GenRad

# INSTRUCTION MANUAL

SE Labs (EMI) Ltd.
NORTH FELTHAM TRADING ESTATE
FELTHAM
MIDDLESEX

# Type 1685 Digital Impedance Meter

B

C4-S1-063

Dept 46

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# GR 1685
# Digital Impedance Meter

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Concord, Massachusetts, U.S.A. 01742
Form 1685-0150-B
January, 1976
ID-0100

# Warranty

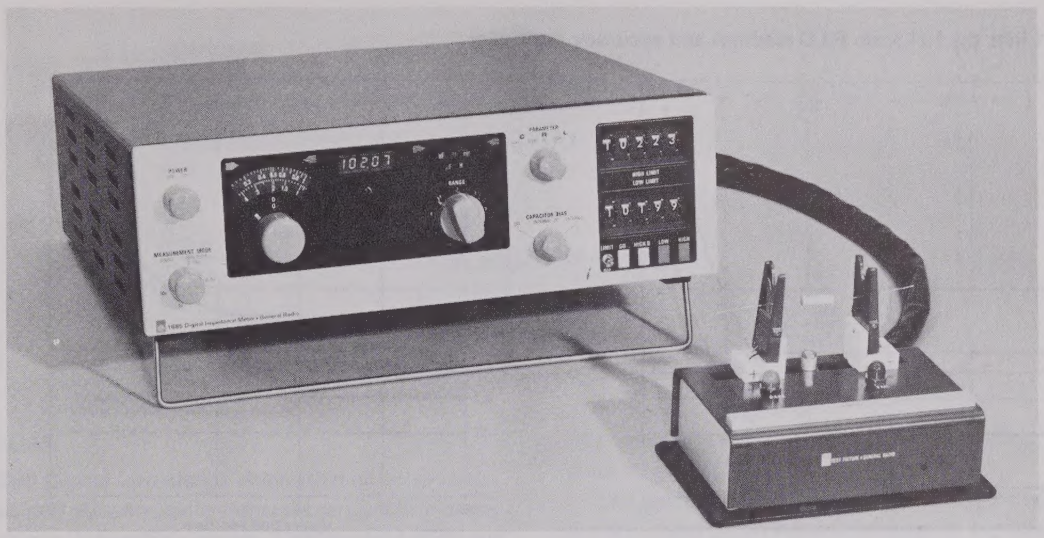
## General Radio

This product is warranted to be free from defects in material and workmanship and, when properly used, will perform in accordance with specifications. Any GR-manufactured instrument, module, or part found not to meet this standard within a period of one year after original shipment will be repaired or replaced at no charge when returned to a GR service facility.

GR policy is to maintain repair capability for a period of ten years after the original shipment and to make this capability available at the then prevailing schedule of charges for any product returned to a GR service facility. Changes in the product not approved by GR shall void this warranty. GR is not liable for consequential damages.

This warranty is in lieu of all other warranties, expressed or implied, including, but not limited to, the implied warranties of merchantability and fitness for a particular purpose.

# Condensed Operating Instructions



To operate the 1685:

a. Connect the cables and/or test fixture to the instrument (paragraph 3.1), If using externally connected equipment for control and/or data recording, refer to paragraph 2.5, if necessary. Set the BIAS switch to OFF.

**WARNING**

**A maximum external bias voltage of 30 volts is recommended for safety reasons. For certain applications, voltages up to a maximum of 100 volts may be used. When a bias voltage greater than 30 volts is used, excercise extreme care to avoid dangerous electrical shock. Full bias voltage appears on test-lead or test-fixture terminals and on the leads of the component under test when an external bias source is connected and the CAPACITOR BIAS switch is set to EXT.**

**Capacitors remain charged after measurement. The user must follow safe procedures to assure proper discharge of measured capacitors. See the WARNING in Paragraph 3.4.1.**

**After measurement of inductors with external bias applied, bias current must be reduced to zero before the inductor is disconnected. See the WARNING in Paragraph 2.6.2.**

**For safety reasons, all personnel operating the Meter must be aware of the potential hazard involved in external biasing of capacitors and inductors.**

**Do not leave the Meter unattended with external bias applied.**

b. Set the PARAMETER switch for the type of part being measured and for the desired test frequency

c. Set the RANGE switch to the applicable range (see para. 3.3). This can be done after turn-on, if desired (step h).

d. If using the optional limit comparator, set the HIGH- and/or LOW-LIMIT digit switches to the desired limit(s) and set the LIMIT switch to LIMIT.

e. Set the MODE switch to either SINGLE or REPETITIVE, and adjust as required if setting to REPETITIVE. Measurement time can be adjusted from 1/4 s to 10 s.

f. Turn-on the instrument and connect a component to the test leads or test fixture and turn on the instrument. If capacitance is being measured, set the CAPACITOR BIAS switch to INTERNAL, EXTERNAL, if appropriate. *Make sure* the bias is set OFF if measuring resistors. Refer to para 2.7 for details on supplying an external bias voltage. Be careful not to touch the lead or fixture terminals if a higher external bias is applied to the instrument.

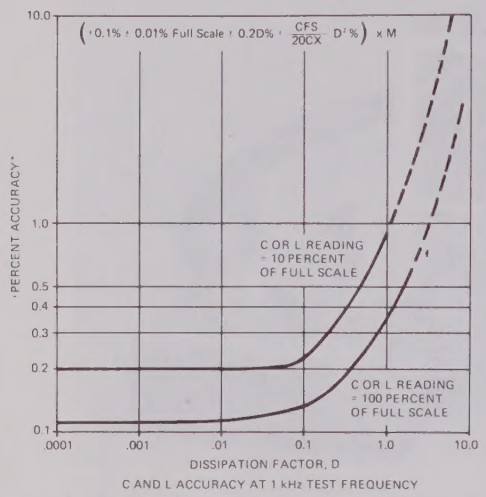
g. Start a measurement (para 3.4) and observe the readout display, range lamps and D-Q lamps, as applicable.

h. Adjust the MODE, RANGE, and D-Q dial, if required (para 3.3).

i. If measuring dissipation factor, D, or quality factor, Q, set the D-Q dial to the desired setting.

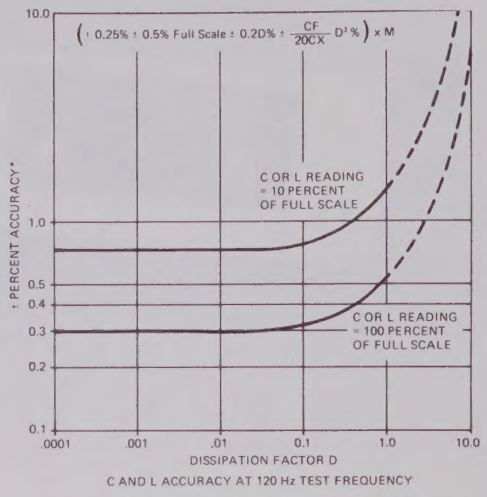
# Specifications

**Note: Table 3-1 lists the full-scale RLC readings and accuracy multiplier.**




C AND L ACCURACY AT 1 kHz TEST FREQUENCY

*MULTIPLY ACCURACY BY M IN TABLE 3-1 FOR EACH RANGE




C AND L ACCURACY AT 120 Hz TEST FREQUENCY

*MULTIPLY ACCURACY BY M IN TABLE 3-1 FOR EACH RANGE

**Accuracy:** Basically, 0.1% for dc and 1-kHz measurements; 0.5% for 120-Hz measurements. See curves for exact accuracies. (±0.1% ±.01% full scale) xM for dc resistance. See Table 3-1 for M values.

**Dissipation Factor/Q Factor:** D = 0 to 10; Q = 0.1 to ∞.

$$D_{MAX\ ERROR} \pm [0.001 + 0.0002 \frac{\text{L or C Full Scale}}{\text{L or C reading}} + 0.05\ (I+D)D]\ xM$$

where M = Accuracy Multiplier**

Q accuracy is same as D accuracy since dial indicates both D and Q. Dial reads both D and Q, and may be set to give D or Q limit or adjusted to give D or Q value.

**Display:** LED display with full scale readings of 19999 at DC and 1 kHz and 1999 at 120 Hz with decimal point and over-range indication. Reads C, R, or L.

**Applied Voltage:** AC: A x 1 V rms max. DC: A x 2 V max, where A = voltage multiplier.** Maximum power is 1/8 W.

**Frequency:** 1 kHz ±2% and 120 Hz, synchronized to line (100 Hz test frequency for 50-Hz line).

**Bias:** For capacitors, 2V internal and 0-100 V external; for inductors, allowable bias current depends on range.

**Measurement Speed/Mode:** Measurements made on command or repetitively at times from 0.25 s to 10 s. Previous measurement is held during period of new measurement.

**Data Outputs (TTL Logic):** Open collector, active low. Each of the following outputs will sink 40 mA (max) from an external source of +30 V (max). Low output = +0.4 V (max); BCD measurement value, decimal points, DQ high, reset, strobe, over range.

**Data Inputs:** REMOTE START: A positive transition of < 1 μs rise time from 0 V < $V_L$ < 0.4 V to +2 V < $V_H$ < 30 V initiates a measurement. LAMP TEST: A ground lights all segments of the right-most four digits of the LED display (8 8 8 8) to check operation of all indicator segments.

**Limit Option:** DATA OUTPUTS (TTL LOGIC): Open collector, active low, Each of the following outputs will sink 40 mA (max) from an external source of +30V (max). Low output = +0.4V (max): busy, go, DQ high, high limit, low limit, fail, SUPPLEMENTARY OUTPUTS: (*Clamp*) This line is to be tied to the external supply (+30V max) to suppress inductive transients from external relay coils. Audio output line to drive a miniature speaker (or headphone) tied between this output and ground. Signal gives ≈ 1/4 sec audio burst, when measured value falls outside the selected high and low limits. (Not activated by DQ failures). (*Interface*): Lines for interfacing with a digital printer (i.e., GR 1785), a component sorter, a component handler for a specific application, and/or to interface with a multiple limit comparator. DATA INPUTS: (*Remote Start*) A positive transition of < 1 μs rise time from 0 V < $V_L$ < 0.4 V to +2 V < $V_H$ < +30 V initiates a measurement. (*Limit Disable*) Performs the same function as the toggle. switch on the front panel of the limit option module: High input turns limit option OFF, OPEN is equivalent to $V_L$. (0 V < $V_L$ < +0.4 V, + 2 V < $V_H$ < +30 V.)

**Environment:** TEMPERATURE: 0 to +50°C operating (increase accuracy multipliers by 10% for each °C above 35°C or below 15°C). −40 to +75°C storage. HUMIDITY: 95% at 35°C.

**Supplied:** Power cord, measurement cable, output-data connector set.

**Power:** 90 to 127 or 180 to 253 V. 48 to 440 Hz, 40 W max.

**Mechanical:** Bench or rack models. DIMENSIONS (wxhxd): Bench, 17.00x5.59x16.25 inc. (432x142x413 mm); rack, 19.00x5.22x16.63 in. (483x133x422 mm). WEIGHT: Bench, 22.5 lb (10.2 kg) net, 31 lb (14.1 kg) shipping; rack, 23.25 lb (10.54 kg) net, 31.75 lb (14.4 kg) shipping.

| Description | Catalog Number 60-Hz Models | 50-Hz Models* |
|---|---|---|
| **1685 Digital Impedance Meter** | | |
| Bench model without Limit Comparator | **1685-9700** | **1685-9800** |
| Bench model with Limit Comparator | **1685-9702** | **1685-9802** |
| Rack model without Limit Comparator | **1685-9701** | **1685-9801** |
| Rack model with Limit Comparator | **1685-9703** | **1685-9803** |
| **1685-P1 Test Fixture, Kevin clips** | **1685-9600** | |

*50-Hz line frequency, 100-Hz test frequency.
**See Table 3-1.

# Introduction—Section 1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## 1.1 PURPOSE

The 1685 Digital Impedance Meter is an all solid-state instrument that automatically measures series capacitance and inductance at two frequencies, 120 Hz and 1 kHz, and measures resistance at DC. These measurements can be made on command or repetitively, with measurement time variable between 0.25 s and 10 s and with results furnished by means of a digital readout display.

The basic accuracy is 0.1% +2 counts for dc and 1-kHz measurements and 0.5% + 1 count for 120-Hz measurements. For DC and 1-kHz measurements, the full-scale digital readout indication is 19999; for 120-Hz operation it is 1999. The decimal points and units are also displayed; the units are displayed on the RANGE switch dial.

The range is manually set. The meter measures capacitance from .01 pF (one digit) to 20,000 $\mu$F, inductance from .01 $\mu$H to 2,000 H and resistance from 0.1 m$\Omega$ to 20 M$\Omega$.

For ac measurements, the dissipation factor, D, or quality factor, Q, is also indicated. The value of D or Q is obtained by a manual dial adjustment. However, if this dial is set to the desired D or Q limit, there is an automatic indication if their value is exceeded.

Data outputs are also furnished for one measurement result and one high D (or low Q) decision to allow data recording, limit comparison, or process control. An optional, built-in, two-limit comparator is available for go/no-go sorting. Multiple-limit comparators, data printers, card punches and handlers are also available from General Radio, both separately or as a system. Meter output levels are standard TTL, open-collector, for total interface flexibility.

The instrument's analog circuit allows low impedances to be measured by means of a four-terminal connection to the unknown, which minimizes lead-impedance effects. Guarded, three-terminal measurements can also be made with negligible error regardless of substantial stray capacitance to ground.

The analog-to-digital conversion of the measurement result is made by an AC-DC ratio meter capable of high accuracy and stability.

## 1.2 GENERAL FUNCTIONAL DESCRIPTION

Refer to Section 4 for a general and detailed functional description of the meter.

## 1.3 GENERAL PHYSICAL DESCRIPTION

The 1685 is available in two models, a relay-rack-mount configuration and a bench-mount configuration. The rack-mount unit is assembled in a metal cabinet and, with a minimum amount of hardware, is ready for mounting in an EIA standard 19-inch relay rack. The bench-mount unit can be set in a tilted position on a bench, for easy viewing of the front panel, by pulling down the bail underneath the instrument.

The unit has its own power supply, including a 0.2 V internal bias supply for capacitors under test. The unit can be operated from 48-440-Hz line voltages of 90 to 127 V and 180 to 253 V, in 5 ranges selectable at the rear panel. Proper fuses for these voltages (1.0 for 100-127 V and 0.5A for 180-253 V) are fitted in fuse holders on the rear panel. Measurement-terminal connectors are furnished on the rear panel. The physical characteristics of the unit are described in the specifications at the front of the manual. Complete dimensions for the bench- and rack-mount units are given in Section 2.

Most of the circuits of the 1685 are on two large circuit boards (excluding the comparator option). One board, the bridge board, is on the floor of the instrument. This board contains the analog measurement circuits, as well as the oscillator that furnishes the 1-kHz and 120-Hz test signals to the part under test.

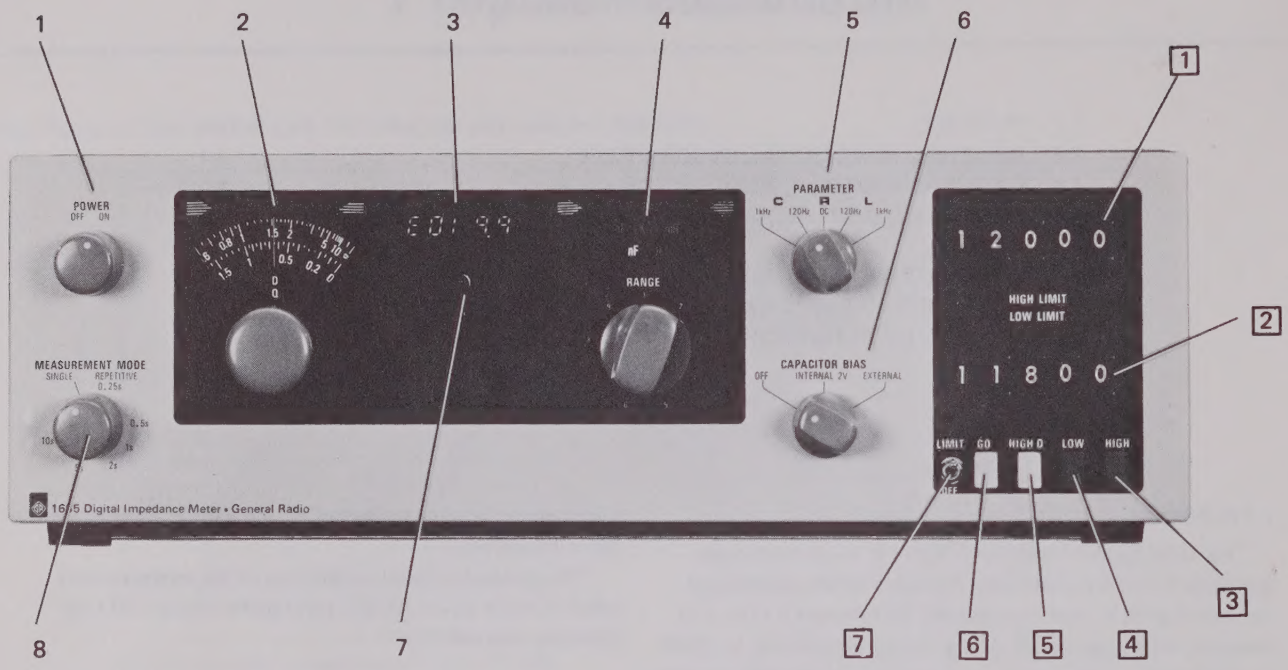



**Figure 1-1. Front-panel controls and indicators, including the optional limit comparator.**

The other board, the logic board, is mounted at the top of the instrument chassis, on hinges for easy access to all circuit-board components and all other components in the unit. The board furnishes timing and control signals for the measurement circuits, logic signals representing measured values that are applied to the display panel meter, which is also mounted on the board, and binary-code decimal logic signals to the rear-panel MEASUREMENT DATA connector for the recording of measurement data by external devices.

Most of the circuit-board test points and adjustments are readily available for easy access. Photographs in Section 5 of the manual identify the locations of various components and parts.

## 1.4 CONTROLS, DISPLAYS, AND INDICATORS

Figure 1-1 shows the 1685 front panel, including the front panel of the optional limit comparator. Table 1-1 identifies and contains a description of the front-panel controls and indicators. Table 1-2 identifies and contains a description of the limit comparator control and indicators.

Figure 1-2 shows the 1685 rear panel, and Table 1-2 identifies and describes the rear panel controls and connectors.

## 1.5 SYSTEMS

Since additional equipment can expand the basic capabilities of most General Radio instruments, including the Impedance Meter, arrangements are available to supply complete systems; inquiries are invited. Each system, custom tailored to individual requirements and including only equipment necessary to perform the required task, is completely assembled and checked as a unit. Such systems have wide application and can be used for laboratory development, production monitoring, final quality assurance, production-lot sorting, incoming inspection, environmental testing, reliability evaluation, etc., on an automatic or semi-automatic basis.

## 1.6 ACCESSORIES SUPPLIED

A power cord (P/N 4200-9625) and a measurement cable (P/N 1685-0291) that furnishes connections to the part under test are supplied with the instrument. The measurement cable is terminated with banana plugs or alligator clips (furnished separately) that allow remote (5-ft.) two-to five-terminal connections to the unknown. If other types of

**Table 1-1**

FRONT-PANEL CONTROLS AND INDICATORS

| Fig. 1-1 Ref. No. | Name | Type | Function |
|---|---|---|---|
| 1 | POWER | 2-position rotary switch | When set to ON, applies power to the instrument. |
| 2 | D, Q dial | Continuously adjustable rotary dial and associated indicator lamps (2) | Upper scale is D factor; the lower Q factor. Range is 0 to 10 for D and 0.1 to ∞ for Q (D=1/Q). Dial can be set to give D or Q limit or adjusted to obtain D or Q value. This is done in conjunction with indicator lamps → ←above the meter, to the left- and right-hand sides. The dial indicates the D or Q value at the point where one light goes out and the other goes on, or when both lamps are lit. As a limit comparator, the lamp to the left- or right-hand side lights if the D or Q of the part under test exceeds or falls below the set limit, as the case may be. The red arrow indicates the failure to meet the limit; the green lamp indicates value meets or exceeds limit. |
| 3 | Digital panel meter | 4-½ numeral readout LED display | Gives visual indication of capacitance, inductance, and dc resistance to 5 places at DC and 1 kHz; 4 places at 120 Hz. |
| 4 | RANGE | 9-position rotary switch and dial and associated indicator lamps (2) | Establishes capacitance, inductance and resistance measurement ranges: 8 ranges for capacitance and inductance and 9 ranges for resistance, all corresponding to the switch position. Table 3-1 lists the corresponding range for each switch position for capacitance and inductance at 120 Hz and 1 kHz and for resistance. The Range lamps →←indicate that the correct range is set when both lamps are extinguished. If only one lamp is lit, the dial should be turned in the direction denoted by the indicator, to obtain the correct setting. |
| 5 | PARAMETER | 5-position rotary switch | Selects the parameter to be measured: capacitance 1 kHz or 120 Hz, inductance 1 kHz or 120 Hz, or dc resistance. |
| 6 | CAPACITOR BIAS | 3-position rotary switch | When set to INTERNAL 2V, furnishes 2 V bias for the capacitor under test. The EXTERNAL position allows an external bias voltage of up to 100 V to be applied to the capacitor under test, via the rear-panel EXTERNAL BIAS connector. |
| 7 | —— | Red LED indicator lamp | When illuminated, indicates meter is making a measurement. |
| 8 | MEASURE-MENT MODE | Continuously adjustable switch | When set to REPETITIVE and adjusted between 0.25 and 10 s, repetitive measurements are made at the established rate. When set to SINGLE, a single measurement is made when initiated by an external device such as a test future, component handler, recording device, etc. connected to the rear-panel. (The panel legend indicates only the approximate rate.) |

**Table 1-2**

COMPARATOR FRONT-PANEL CONTROLS AND INDICATORS

| Ref. No. | Name | Type | Function |
|---|---|---|---|
| 1 | HIGH LIMIT | 5-numeral digit-switch, including decimal point | Establishes the upper measurement limit for comparison. |
| 2 | LOW LIMIT | 5-numeral digit-switch, including decimal point | Establishes the lower measurement limit for comparison. |
| 3 | HIGH | Indicator lamp | Lights if the measured value exceeds the selected HIGH LIMIT. |
| 4 | LOW | Indicator lamp | Lights if the measured value falls below the selected LOW LIMIT. |
| 5 | HIGH D | Indicator lamp | Lights if the D of the unknown component is higher (or Q is lower) than the D value set on the D-Q dial. |
| 6 | GO | Indicator lamp | Lights when measured value of the part under test is within the limits established by the LIMIT switches. |
| 7 | LIMIT | Toggle switch, subminiature 2-position SPDT | When set to LIMIT, enables limit comparator. |

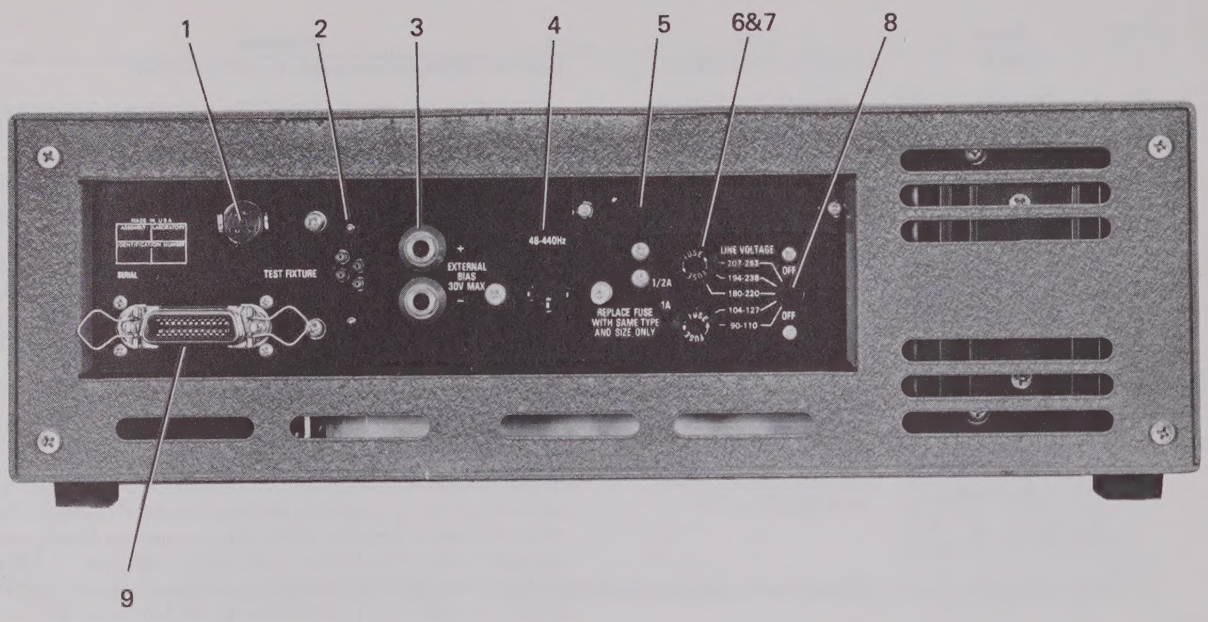



**Figure 1-2. Rear-panel view.**

**Table 1-3**
REAR-PANEL CONTROLS AND CONNECTORS

| Ref. No. | Name | Type | Function |
|---|---|---|---|
| 1 | J7 | Multiple-socket connector with locking ring (Amphenol type 126-218) | Furnishes connection to 1685-P1 test fixture for fixture's limit indicators. (Refer to Section 2 for details.) Can be wired for other system applications. Mates with Amphenol 126-217 plug, or equivalent. |
| 2 | TEST FIXTURE | Multiple-socket connector, coaxial, 7-pin | Connection for 1685-0291 lead set, 1685-P1 test fixture or component handler. Mates with Amphenol 50064-1 plug (block) or 200867-2 (screw-assembly plug for use with the Type 50064-1). Refer to Section 2 for details. |
| 3 | EXTERNAL BIAS 100 V MAX, +, – | 3/4-inch-spaced banana jacks | High- and low-side connections for an external bias supply of up to 100 V. This voltage, when used, is available at the test fixture + current terminal when the front-panel CAPACITOR BIAS switch is set to EXTERNAL. |
| 4 | 48-440 Hz | Safety type line-voltage plug, 3-wire (IEC Standard) | Accepts 3-wire ac-line-cord, Belden SPH-386, or equivalent. Use GR Power Cord P/N 4200-9625. |
| 5 | —— | Socket, 30-pin; accepts GR 4320-1023 connector and cover assembly | Receptacle for supplying measurement data for recording by external equipment and for handling various input and output control signals for system use. (Refer to Section 2 for details.) |
| 6 | 1/2 A | Extraction Post fuse holder | Protects instrument on 3 highest line-voltage ranges. Fuse is type MDL, Bussman or equivalent. |
| 7 | 1 A | Extraction Post fuse holder | Protects instrument on 2 lowest line-voltage ranges. Fuse is type MDL, Bussman or equivalent. |
| 8 | LINE VOLTAGE | Rotary switch, screwdriver adjustable | Switches line voltage connection to one of five ranges. |
| 9 | —— | Socket, 24-pin; accepts Cinch or Amphenol 57-30240 plug | Receptacle for furnishing comparison data to peripherals and accepting some control signals for the meter and comparator. Refer to Section 2 for details. |

connectors are desired, the user can remove the alligator clips and install other connectors on the cable.

An output data connector set (P/N 4230-1023) is also furnished with the instrument. This set makes measurement data in BCD form available to external recording equipment. It also accepts and furnishes some control signals for starting meter measurements, actuating component handler and data recording equipment, etc.

The power cord is a 7-ft., 3-wire, AWG No. 18 cord with molded connector bodies. One end with a Belden SPH-386 socket fits the instrument. The other end is stackable (hammerhead), conforming to ANSI standard X73.11-1973.

## 1.7 ACCESSORIES AVAILABLE

### 1.7.1 Limit Comparator

A built-in impedance limit comparator is offered as an option with the meter. The comparator allows wide ranges of resistance, capacitance, inductance and dissipation factor, D, and storage factor, Q, (in conjunction with the meter's D-Q control) to be compared to any upper and/or lower limits within the range of the meter.

The comparator is a self-contained unit that enhances the operation of the Impedance Meter, making the meter particularly useful for manual, semi- or fully-automatic selection and sorting applications, as well as intricate laboratory measurements. Visual indications of comparison results as well as respective control signals available for use by external equipment permit these various operations to be easily performed with a minimum of operator intervention of involvement.

Comparisons of quantities usually requiring laboratory techniques can also be easily made, such as: small impedance differences, semiconductor capacitances, capacitance drift with temperature, etc. And, with suitable recorders such as the GR Type 1785 Line Printer or other recorders, records of all types of data can be kept, including changes in measurements as a result of environmental effects.

A GR 1784 Multiple-Limit Comparator that makes comparisons of up to 4 sets of limits is also avaialble. See Table 1-5.

### 1.7.2 1685-P1 Test Fixture

This fixture, available as an accessory and employing Kelvin clips for axial-lead components, furnishes effectively a 5-terminal measurement connection for components and parts under test. The fixture permits rapid manual measurements of components while providing high accuracy by reducing the effects of stray impedances on measurement accuracy.

Figure 1-3 shows the fixture, and Figure 6-16 is the schematic diagram of the fixture. When the fixture is connected to the rear-panel TEST FIXTURE connector, and the top to the fixture is pressed down, a 1685 measurement operation will start. Indicator lamps mounted on the fixture give GO/NO-GO indications when used with the limit comparator option.

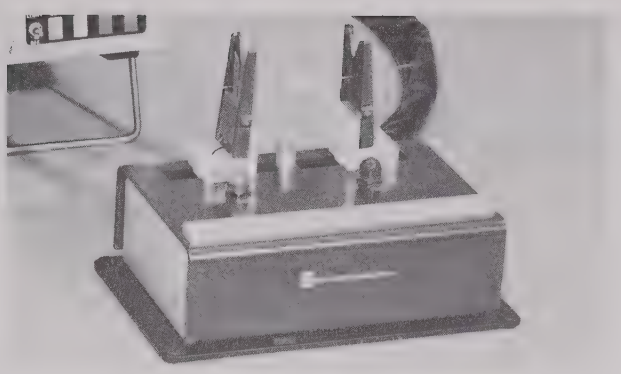


**Figure 1-3. Test Fixture.**

### 1.7.3 Other Accessories Available.

Other accessories that are available allow such instrument enhancements as data printing, card punching and externally applied bias voltages, and also aid in performing operational checks, calibration and testing. Table 1-4 lists GR manufactured accessories available for use with the 1685. Consult GR for other items available, such as component handlers, other data recorders, and environmental test devices that can be supplied separate or on a system basis by GR. Table 1-5 lists related accessories available.

## 1.8 AVAILABLE PATCH CORDS AND ADAPTORS

The rear-panel EXTERNAL BIAS connection is a standard 3/4-inch spaced pair of banana jacks that accepts 3/4-inch standard banana plugs. Table 1-6 lists the available interconnection accessories for this and possible other applications.

**Table 1-4**

INSTRUMENT ACCESSORIES AVAILABLE

| Name | GR Part, Option or Type No. | Function |
|---|---|---|
| 1685-P1 Test Fixture | Type 1685-P1 (P/N 1685-9600) | Test fixture with *Kelvin clips* for axial-lead components |
| Impedance Limit Comparator | Must be ordered with instrument. | Unit that compares measured values against upper and/or lower limits established by means of digit switches on the comparator. Unit furnishes visual indications of high, low, or acceptable measured values of C, R, and L and out-of-limit indications for D and Q. The unit also furnishes associated signals for use by external equipment. A connector plug (P/N 4220-3024) is also supplied for this purpose. |
| Rack Adaptor Set | P/N 0480-9703 | Allows unit to be mounted in a standard 19-in. EIA rack. |

**Table 1-5**

RELATED ACCESSORIES AVAILABLE

| Name | Type or Part No. | Function |
|---|---|---|
| Data Printer | Type 1785 | Precise, compact, and economical means of recording measurement data. Has up to 21-column capacity with a printing rate of three lines per second minimum. A two-color ribbon can be controlled to print red or black on roll and/or fan-fold paper. |
| Multiple Limit Comparator | **Type 1784** | Designed for use with the 1685 Digital Impedance Meter and 1683 Automatic RLC Bridge. Makes comparisons for up to 4 sets of limits, each containing a high and low value. Lamps (and electrical TTL open collector, active low outputs for external use) are furnished for high, low and pass indicators for each set of limits. Limits can be set for priority sorting, from first set of limits to fourth set. Indicator lamps are also furnished for priority sorting, total limit failures, and loss-limit failures. Unit is also stackable, with all data available as output via a 50-pin connector. |
| NOTE<br>Refer to Table 5-1 for information concerning the standards required for particular test or calibration procedures. | | |
| Reference Standard Capacitor | Type 1404-A (1000 pF),<br>1404-B (100 pF),<br>1404-C (10 pF). | Instrument check, calibration, and test. |
| Standard Capacitors | Type 1409-9706 (.001 μF)<br>-9712 (.01 μF)<br>-9720 (0.1 μF)<br>-9725 (1.0 μF).<br>Accuracy ±.05% of nominal capacitance. | Instrument check and calibration. |
| Decade Capacitor | Type 1412-BC Decade Capacitor, 50 pF to 1.11115 μF, accuracy ±(0.5% ±5 pF). | Instrument check, calibration and test. |
| Precision Decade Capacitor | Type 1413; 0 to 1.11111 μF, .05% basic-accuracy. | Instrument check, calibration and test. |
| Decade Capacitor | Type 1419-K; 100 pF to 1.10 μF, accuracy 0.5%. | Instrument check, calibration and test. |
| Precision Decade Capacitor | Type 1423; 100 pF to 1.111 μF, ±.05% basic accuracy. | Instrument check, calibration and test. |
| Standard Resistors | Type 1440-9601 (1 Ω)<br>-9611 (10 Ω)<br>-9621 (100 Ω)<br>-9631 (1 kΩ)<br>-9641 (10 kΩ)<br>-9651 (100 kΩ)<br>-9661 (1 MΩ)<br>Also, 0.1 Ω and .01 Ω. | Extremely stable resistance standards for checking or calibrating the meter with accuracy of ±.01% for all units except 1 Ω, which is .02%. |
| Decade Resistor | Type 1433-H, .01% accuracy, 11,111,111 Ω total. | Instrument check, calibration and test. |
| Decade Resistor | Type 1434-G, .02% accuracy, 1,111,111 Ω total. | Instrument check, calibration and test. |

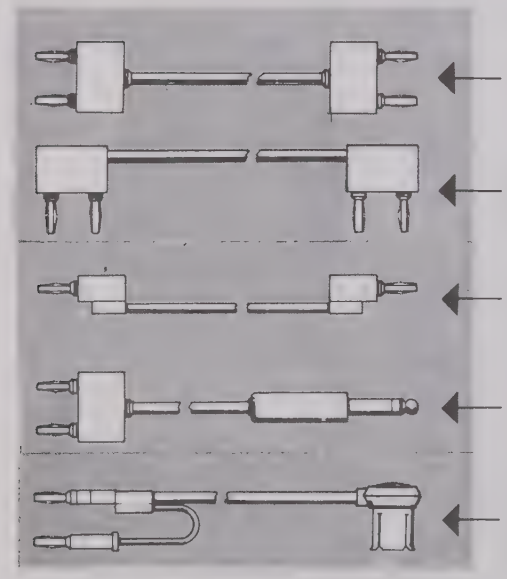
**Table 1-5 (continued)**

RELATED ACCESSORIES AVAILABLE

| Name | Type or Part No. | Function |
|---|---|---|
| Programmable Decade Resistor | Type 1435, 0.2% basic accuracy, 10 Ω to 1.11 MΩ. | Instrument check, calibration and test. |
| Decade Inductor | Type 1491-G, 0.1 mH to 11.111 H, accuracy ±2% to 0.6%. | Instrument check, calibration and test. |
| Standard Inductors | Type 1482-T (10 H)<br>1482-P (1 H)<br>1482-L (100 mH)<br>1482-H (10 mH)<br>1482-E (1 mH).<br>Accuracy ±0.1% nominal inductance.<br>1482-B (100 μH)<br>Accuracy 0.25%. | Instrument check and calibration. |
| Patch Cords and Adaptors | Type 274 | Connections for external bias supply and testing. Refer to the GR catalog, which contains a wide range of cables and connectors for most applications. |

**Table 1-6**

AVAILABLE INTERCONNECTION ACCESSORIES



| TYPE NO. | DESCRIPTION | CATALOG NO. |
|---|---|---|
| 1560-P95 | Adaptor cable, double-plug to telephone plug, 36" | 1560-9695 |
| 874-R33 | Coaxial patch cord, two plugs to GR874, 36" long | 0874-9690 |

# Installation—Section 2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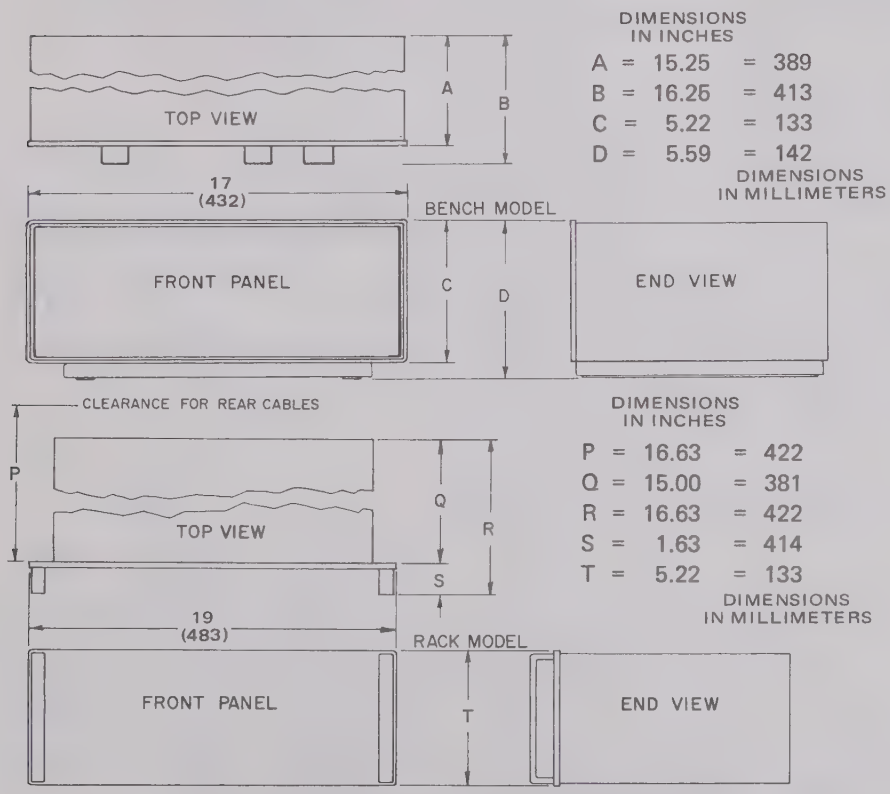



**Figure 2-1. Meter dimensions, in inches and millimeters.**

## 2.1 INSTRUMENT LOCATION

The 1685 Meter can be operated in bench- and rack-mount configurations. Keep the connections to the parts under test away from electromagnetic fields that may interfere with measurements.

## 2.2 DIMENSIONS

Figure 2-1 shows the overall dimensions of the 1685 in bench- and rack-mount configurations.

## 2.3 MOUNTING

Either model (bench- or rack-mount) can be converted to the other by the installation of a simple conversion kit.

### 2.3.1 Bench Mounting

The bench-mount cabinet is made of formed and welded 1/8-in. aluminum finished in baked-on, medium gray crackle paint and has a bail to allow easy viewing of the instrument. The instrument is retained in the case by four rear-panel

screws held in place by O-rings to prevent loss. To remove the instrument from its case, loosen the four rear panel screws and withdraw the instrument. Slides on the instrument case guide insertion and withdrawal. To insert the instrument into the case carefully push it all the way into the case, making sure to keep all cables clear of the case. Secure the four rear-panel screws.

### 2.3.2 Tilting

The bench models of the meter are delivered completely assembled in a metal cabinet, ready for bench use. A convenient bail, located along the bottom front edge of the instrument, can be pulled down to raise the front and provide a better view of the front-panel indicators. To tilt the instrument, pull down on the bail.

### 2.3.3 Rack Mounting

*Bench Model.* To convert to a rack model, proceed as follows:

a. Order a 0480-9703 rack adaptor set.

b. Disconnect any cabling from the rear panel of the instrument, loosen the four Phillips-head screws on the rear panel (the screws are held in place on the cabinet by rubber O-rings to prevent loss), and slide the cabinet off the instrument.

c. Push out the four knockouts (c); use a punch or similar tool and push out from the inside of the cabinet.

d. If the instrument is to be mounted directly above another instrument, push out the four rubber feet attached to the bottom of the cabinet.

e. Attach the rack adaptors with the four screws (L) as shown in Figure 2-2.

f. Replace the cabinet on the instrument and secure in place with the Phillips head screws.

g. Install the instrument in the rack; see the next paragraph.

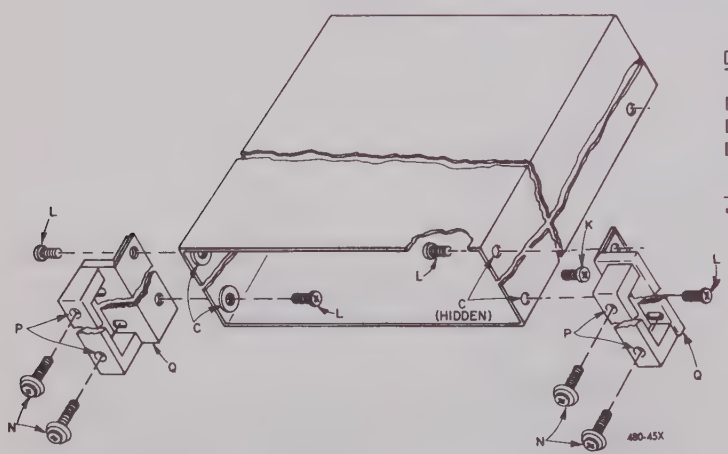



**Figure 2-2. Rack-mount assembly.**

### 2.3.4 Rack model

For installation in an EIA standard 19 in. relay rack, Includes a tiltable bench-cabinet assembly and a 0480-9703 rack-adaptor set. To install the rack-adaptor set, perform steps b through f above. To convert to a bench model, simply remove the rack adaptor set and replace the rubber feet (with bail stand) if removed.

### 2.3.5 Rackmounting (rack models).

To install a rack-model instrument in an EIA standard 19-in. relay rack, insert the instrument in the rack and secure it to the rack with the four rear-panel screws (N); no rear support is necessary.

## 2.4 EXTERNAL-DATA CONNECTIONS.

### 2.4.1 General.

An output-data connection set allows the recording of measurement data by means of externally connected data

| BCD DATA OUTPUTS | | | PIN | SIGNAL OUTPUTS | | PIN |
|---|---|---|---|---|---|---|
| Most-Significant Digit | $\overline{17}$ | | 8 | STROBE (after time) | | 3 |
| | $\overline{16}$ | 8 | 14 | $\overline{E}$ (overrange, or error) | | 4 |
| | $\overline{15}$ | 4 | M | | | |
| | $\overline{14}$ | 2 | D | | | |
| | $\overline{13}$ | 1 | B | $\overline{\text{RESET}}$ | | 10 |
| | $\overline{12}$ | 8 | P | $\overline{\text{HID}}$ (high D, low Q) | | 11 |
| | $\overline{11}$ | 4 | L | | | |
| | $\overline{10}$ | 2 | C | | | |
| | $\overline{9}$ | 1 | A | INTERFACE 1 | Connected only for external applications, as required | E |
| | $\overline{8}$ | 8 | N | | | |
| | $\overline{7}$ | 4 | K | INTERFACE 2 | | 5 |
| | $\overline{6}$ | 2 | F | | | |
| | $\overline{5}$ | 1 | 1 | | | |
| Least-Significant Digit | $\overline{4}$ | 8 | R | SIGNAL INPUTS | | |
| | $\overline{3}$ | 4 | J | | | |
| | $\overline{2}$ | 2 | H | | | |
| | $\overline{1}$ | 1 | 2 | $\overline{\text{LT}}$ (LAMP TEST) | | 6 |

| DECIMAL-POINT OUTPUTS* | | | | |
|---|---|---|---|---|
| Lamp 4 decimal | ADP | 9 | REMOTE START | 7 |
| Lamp 3 decimal | BDP | 12 | | |
| Lamp 2 decimal | CDP | 13 | GROUNDS | S & 15 |

*Lamp 1 is least significant digit (LSD).

**Figure 2-3. Measurement data connector, as viewed from the rear of instrument.**

Table 2-1

MEASUREMENT – DATA CONNECTOR SIGNALS

| Signal Name | Pin No. | Function and Description |
|---|---|---|
| BCD DATA OUTPUTS | As identified in Figure 2-3 | Measurement data in BCD form. All data outputs are open-collector, active low. Details on logic levels are given in the text. In the 1-kHz mode of operation, the most significant digit is at pin 8. In the 120-Hz mode, it is at pin 8. Note that all active lows (logic 0) listed in this table are negative true. |
| ADP, BDP, CDP | 9, 12 & 13 | Decimal-point indicator signals for lamps DS4, DS3, & DS2 respectively. Logic 0 is active function. Refer to Table 3-1 for placement of decimal points for various ranges. Refer to Figure 6-11, if necessary, for illustration of LED lamps showing decimal-point placement. |
| STROBE | 3 | When logic 0, indicates data available for recording. Refer to timing diagram, Figure 6-9, if necessary. |
| $\overline{E}$ | 4 | When logic 0, indicates established range is exceeded (1999 counts exceeded in 120-Hz mode; 19999 counts exceeded in 1-kHz mode). Logic 0 indicates all meter circuits reset (although previous displayed value remains displayed until just before STROBE occurs) for new measurement sequence. |
| $\overline{HID}$ | 11 | Logic 0 indicates D limit is exceeded (or Q limit not obtained). Signal is taken from the high-limit D indicator lamp. |
| INTERFACE 1 & INTERFACE 2 | E and 5, | Available connections for external equipment, to be used as required. Provides hardware connections between peripheral equipment connected to the meter, and any other peripheral equipment (if any) connected to the limit-comparator option. |
| LT (lamp test) | 6 | Input connection for testing the LED display. When a ground is applied to the pin, the LED's should light, displaying 8888 to check operation of all indicator segments of the four least significant digits. Does not light the decimal points. |
| REMOTE START | 7 | Input connection for remotely starting a measurement sequence. Positive transition of input step initiates measurement cycle: $0\ V < V_L < 0.4\ V$; $+2\ V < V_H < +30\ V$ (Open circuit is equivalent to $V_L$ input.) |
| Grounds | S & 15 | Ground-reference connections. |

printers and recorders. The connector also provides for the application of some meter control signals furnished by peripheral devices. Figure 2-3 shows the connector and identifies the signals available on the applicable socket pin; Table 2-1 contains a description of the signals furnished by the connector. The information in Figure 2-3 and Table 2-1 can be used to assemble a cable through which the measurement data can be obtained.

The output-data connector set (P/N 4230-1023), supplied with the meter, consists of a connector and cover assembly (P/N 4230-1023). The connector (P/N 4230-5530) is a printed-circuit, 15-position, 30-contact type connector that has solder terminals for connecting cable wires. A cover that is a part of the cable-connection kit fits over the solder terminal side of the connector. When the cable is made up, the connector, which is now part of the cable, connects to the instrument's printed-circuit logic-board terminals, via the cutout in the instrument's rear panel.

The connector is keyed by means of mating-hole terminals on both ends so that the connector will not seat properly if it is installed the wrong way on the circuit board connector.

All data outputs (including limit-comparator outputs) are standard TTL ($T^2L$) logic, open-collector, active low. Each output is capable of sinking up to 40 mA, maximum, from an external source of up to +30 V. The low output is +0.4 V, maximum. Open-collector operation furnishes total interface flexibility. If the *logic* board *outputs* are used to drive logic circuits, the user need only *add pullup resistors* to the peripheral logic devices, if not already connected. This is not required for the optional comparator's outputs. The data outputs include BCD measurement value, decimal points, D-Q high, reset, strobe, and over range. All outputs can be inverted (as a group) to be open-collector, active high, by a simple plug-in substitution of the output IC (a type 7407 hex buffer/driver) with a type 7406 hex inverter buffer/driver (or types 7404, 7405, 7416, and 7417, if desired).

**Figure 2-4. Comparator connector S05, as viewed from rear panel.**

Provisions are made for two control inputs, remote start and lamp test. A positive transition, step input initiates a measurement cycle; with 0 V $<V_L<$0.4 V and +2 V $<V_H<$+30 V. Open-circuit is equivalent to the $V_L$ input.

A ground at the lamp-test input lights all segments of the four right most digits of the LED display (8888) to check operation of all indicator segments of the four least significant digits. It does not check decimal points.

### 2.4.2 Comparator Data

*Data Outputs.* These outputs from the comparator option are via socket S05 at the rear of the board. In addition, two signals, PASS and FAIL, are furnished to connector J7 on the rear panel, for use with the -P1 test-fixture, which has PASS-FAIL indicator lamps. These latter two signals are routed to J7 via connector S06 inside the unit. Connection need then only be made to J7 for the PASS-FAIL indications.

The connector on the rear of the "A" board is a 24-pin GR 4220-4024 (Cinch or Amphenol 57-40240) socket that mates with a GR 4230-3024 (Cinch or Amphenol 57-30240) plug. The plug is furnished by GR. Figure 2-4 shows the socket, as viewed from the rear of the instrument, Table 2-2 lists the comparator signals, their connections, and their function.

**Table 2-2**

COMPARATOR EXTERNAL DATA

| Signal | Connector & Pin No. | Function |
|---|---|---|
| PASS | J7, D | Lights test fixture PASS indicator when device passes limit comparisons. |
| FAIL | J7, H | Lights test fixture FAIL indicator when device fails a high or low comparison. |
| CLAMP | S05,5 | When connected to source used to operate external device(s), prevents voltages exceeding +30 V from saturating the output open-collector drivers, as described in this paragraph. Usually used with inductive loads (such as relays) where spikes may be present. Refer to description in this paragraph for details and for information necessary to prevent possible damage to equipment. |
| AUDIO OUT | S05,6 | Audio output for use with external speaker or headphone connection between output and ground. Gives approximately 1/4-s burst of 250 Hz when value falls outside any or both limits. Not activated by D-Q failure. |
| GND | S05, 11, 12 | Ground connections for speaker or headphone. |
| $\overline{\text{BUSY}}$ | S05, 13 | When high (open collector) indicates meter and comparator busy. Goes low at time of reset and goes high when comparison completed (low and high comparison, even if high limit not used). |
| $\overline{\text{LOW}}$ | S05,14 | Goes low if value lower than established low limit. LOW lamp lights at same time, FAIL output goes low, and GO lamp is held extinguished. |
| $\overline{\text{HIGH}}$ | S05, 17 | Goes low if value higher than established high limit. HIGH lamp lights at same time, FAIL output goes low, and GO lamp is held extinguished. |
| $\overline{\text{HID}}$ | S05,15 | Goes low if dissipation factor exceeds limit. (left-hand D lamp lit on instrument) or if quality factor Q is below the established limit (left-hand lamp lit). The GO lamp is held extinguished and signal GO is held high. |
| $\overline{\text{GO}}$ | S05,16 | Goes low at end of comparison if value is within established limit (s). GO lamp lights and signal BUSY goes low. |
| $\overline{\text{FAIL}}$ | S05, 2 | Goes low when value exceeds established low and/or high limit. |
| INTERFACE 1 & 2 | S05, 19 and 20, respectively | Connections for use with peripherial equipment to perform specific operations. Lines are connected to logic board (Figure 6-10). They can be connected to various points on the board, as required. |
| REMOTE START | S05,18 | Input line. Starts measurement cycle on the positive transition of a step input: 0 V $<V_L<$+ 0.4 V; high is +2 V $<V_H<$+30 V, where open circuit is equivalent to $V_L$, or low, input. |
| LIMIT DISABLE | S05, 1 | Performs same function as the front-panel LIMIT OFF switch. High input turns limit option off. |

Comparator output data is also TTL compatible and is open-collector, active low. The output signals available at the connector are busy, go, high D-Q, high, low fail, and clamp, as illustrated in Figure 2-5. Three other outputs are also furnished: 1 kHz, interface 1, and interface 2. Signal "CLAMP" is for use when driving inductive loads (such as relays) or when spikes are present, to prevent voltages from exceeding +30 V, the maximum breakdown voltage of the hex buffer-drivers. The TTL open-collector feature allows high-voltage output for interfacing with high-level circuits (such as MOS) or for driving high-current loads, such as lamps or relays.

CAUTION

For proper operation, use only positive voltages and one voltage level when using the "CLAMP" connection.

When the "clamp" feature is used, the common cathode point of six diodes, whose anodes are tied, one each, to the six data-output lines, is tied to the clamp. The "CLAMP" line is to be tied to the external supply (+30 V, max.) to suppress inductive transients from external relay coils or similar devices.

The audio output line can be used to drive a miniature speaker or headphone tied between this output and ground. The signal gives a 1/4-s burst of 250 Hz frequency when the measured value is outside the established limits.

The INTERFACE lines allow external devices such as printers, multiple-limit comparators, component handlers, etc., to be connected for specific applications. These lines can be tied internally to various control signals available on the comparator or logic boards in the instrument. Refer to the schematic drawings in Section 6, if necessary.

*Data Inputs.* These include a remote-start that initiates a measurement cycle on the positive transition of a step input: 0 V $< V_L <$+0.4 V to +2 V $< V_H$ +30 V. (Open is equivalent to $V_L$ input.) A limit-disable feature performs the same function as the toggle switch on the limit option front panel. A high input turns the limit option off. (Open circuit is equivalent to $V_L$, where low $0 < V_L <$+0.4 V and high is +2 V $< V_H <$+30 V.)

### 2.4.3 Interchanging Active Levels

The active levels can be interchanged; that is, active lows can be substituted for highs, and vice versa, by the substitution of 7407 hex buffer-drivers for 7406 hex inverter buffer-drivers, and vice versa. If the comparator option is included in the instrument, the type 7407 on the comparator 'A' board,can be interchanged with any of the 3 type 7406's on the logic board, if this application is suitable. In this case, the logic board data output would probably not be used. This will reverse the active outputs of the comparator board and certain outputs (if desired) of the logic board. Full substitutions can be made to change all levels. In addition, type 7404, 7405, 7416, and 7417 packages can be substituted for any 7406 or 7407 output circuit.

## 2.5 TEST-FIXTURE CONNECTION

The rear-panel TEST FIXTURE provides, effectively, a 5-terminal connection for the Type 1685-0291 test-cable assembly and for the -P1 test fixture, available as an option. In addition, connection J7 on the rear panel furnishes PASS-FAIL signals for the test-fixture indicator lamps, and connects the "start measurement" signal, produced when the test fixture is pressed, to the meter. Figure 2-6 shows the TEST FIXTURE connector and identifies the contacts that connect to the meter's measurement terminals, which are described in Section 4. The connector is a multiple socket, 7-pin coaxial connector that mates with an Amphenol

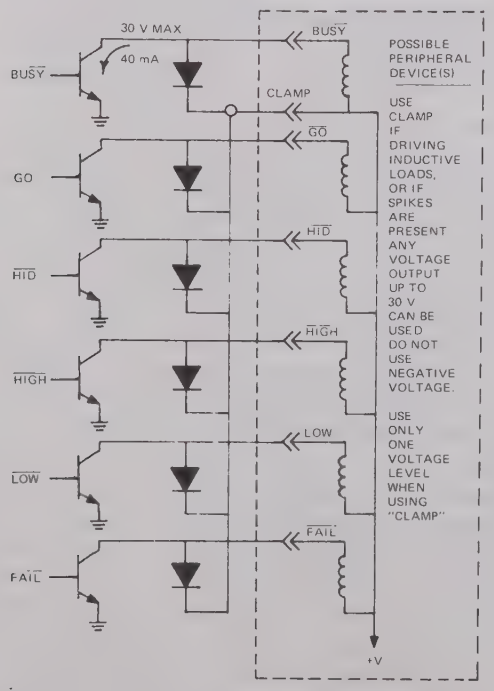



**Figure 2-5. Comparator output signals that can be used with "clamp" function.**

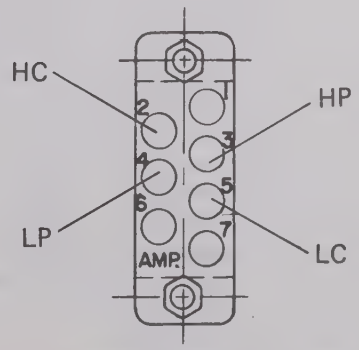
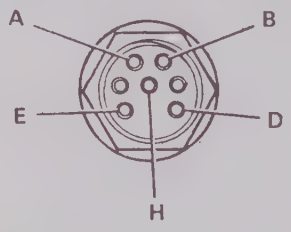



**Figure 2-6. TEST FIXTURE socket connection, with measurement terminals identified.**

50064 plug (block-type) or 200867-2 (screw-assembly for use with the Type 50064-1) plug. The plugs furnished with the test-cable assembly and the test fixture are screw assembly types. All that need be done is insert the plug into the connectors and then fasten securely by means of the screws on the plug.

To use the test-fixture limit indicators (PASS-FAIL) and start-measurement feature, it is necessary to connect the other cable on the fixture to rear-panel connector J7. The rear-panel is a multiple-socket type with a locking ring (Amphenol type 126-218), and it mates with an Amphenol 126-217 plug, or equivalent.

Figure 2-7 shows the rear-panel connector and identifies the signals applied to its contacts.




| Pin | Function | Remarks |
|---|---|---|
| A | Ground | Activated when fixture cover is pressed |
| B | "Start" connection | |
| D | "Pass" signal | Activates PASS indicator |
| E | +5V | |
| H | "Fail" signal | Activates FAIL indicator |

**Figure 2-7. J7 socket connections, as viewed from the rear of instrument.**

## 2.6 EXTERNAL BIAS

### 2.6.1 Biasing Capacitors*

Up to 100 V can be applied externally to the instrument for the biasing of capacitors. A low-impedance, regulated power supply is recommended.

The bias supply should have an output impedance low enough so that the applied ac test voltage will not be appreciably changed when applied to the unknown. The output impedance required depends on the measurement range being used, as illustrated in Figure 2-8. On the top 2 ranges, the supply may have a rather high impedance. On the 5 middle ranges, the output impedance should be small compared to 10 ohms, and on the lowest two ranges it should be small compared to 1 ohm. If a shunt capacitor is used to obtain this low impedance, its reactance can be as large a one-half the above values.

Output impedance is generally not a problem for "hard-regulated" supplies. However, such supplies generally do not operate properly with current flowing into them. One way to prevent a negative dc regulator current is to load the regulator with a resistor such that the dc current is greater than the peak ac current ($0.1\sqrt{2}$ A).

Refer to Figure 2-9. A value of at least 0.15 A dc is recommended. This simple method results in considerable

*Refer to Section 3 for details on time required to charge capacitors.

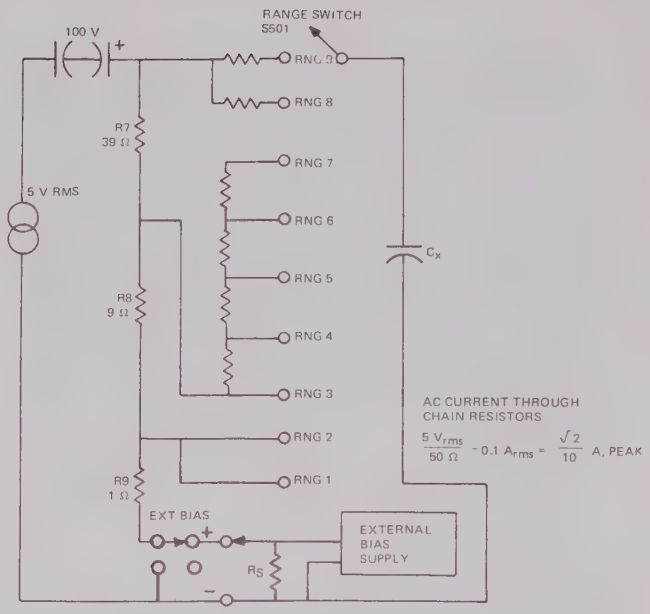
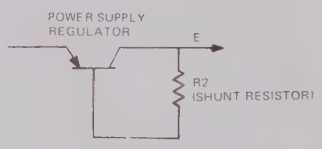



**Figure 2-8. External bias connection, with resistor.**




$$\text{POWER} = \frac{E^2}{R2}$$

TO KEEP ACV CORRECT

$Z_o << R_B$,

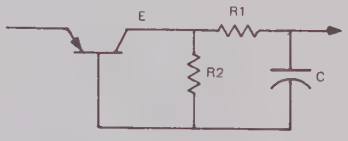
WHERE

$R_B$ = R9 (1 Ω, THE CHAIN RESISTOR).

TO PREVENT NEGATIVE REGULATOR CURRENT

$$\frac{E}{R2} > \frac{\sqrt{2}}{10}\ \text{A}.$$

**Figure 2-9. External bias network for C ranges 1 and 2.**




$$\text{DC POWER} = \frac{E^2}{R2}$$

TO KEEP ACV CORRECT

$$\frac{1}{\omega C} << R_B,$$

WHERE

$R_B$ = R8 AND R9 OR JUST R9 (10 Ω).

TO PREVENT NEGATIVE REGULATOR CURRENT

$$\frac{E}{R2} > \frac{\sqrt{2}}{10\sqrt{1+\omega^2 R1^2 C^2}}\ \text{A}$$

OR APPROXIMATELY

$$\frac{E}{R2} > \frac{\sqrt{2}}{10\,\omega R_1 C}\ \text{A}.$$

**Figure 2-10. External bias network for C ranges 3-7.**

Table 2-3
INDUCTOR BIAS CURRENTS

| Range | Test Frequency 1kHz | 120kHz | $I_{dc}$, Max. | R1 | R2 | R3 |
|---|---|---|---|---|---|---|
| 1 | 20μH | 200μH | 100 mA | 1Ω | 0 | 1Ω |
| 2 | 200μH | 2mH | 100 mA | 1Ω | 0 | 10Ω |
| 3 | 2mH | 20mH | 100 mA | 10Ω | 0 | 10Ω |
| 4 | 20mH | 200mH | 80 mA | 10Ω | 82Ω | 100Ω |
| 5 | 200mH | 2H | 8 mA | 10Ω | 820Ω | 1kΩ |
| 6 | 2H | 20H | 800 μA | 10Ω | 8.2kΩ | 10kΩ |
| 7 | 20H | 200H | 80 μA | 10Ω | 82kΩ | 100kΩ |
| 8 | 200H | 2000H | 50 μA | 50Ω | 270K | 100kΩ |

power dissipation at higher bias voltages. A more practical method is to use the circuit illustrated in Figure 2-10, where the ac current is attenuated before reaching the regulator, so that the dc current required can be substantially less.

### 2.6.2 Biasing Inductors

**WARNING**

**Biased inductors store energy that can be dangerous to the operator of the Meter. Full bias voltage appears on test-lead or test-fixture terminals and on the leads of the component under test when an external bias source is connected and the CAPACITOR BIAS Switch is set to EXT. To safely disconnect an inductor, reduce the bias voltage to zero before disconnecting the inductor. For safety reasons all personnel operating the Meter must be aware of the potential hazard involved in external biasing of inductors and capacitors.**
**Do not leave the Meter unattended with external bias applied.**

The simple method of biasing inductors (Figure 2-11) is limited by several considerations, the most stringent of which is that the voltage drop across $R_S$ must be somewhat less than 10 V to allow linear operation of amplifier U2.* Table 2-3 lists the maximum dc current limit that should be supplied by an external bias source in order not to saturate U2 and its associated power amplifier.

Another limitation is the voltage rating (100 V) of the oscillator-isolating capacitor and the power dissipated in R2. (Refer to Table 2-3.) The maximum current on the lowest range, therefore, is limited to 100 mA, the current limit of amplifier U2 and its associated power amplifier.

Much larger bias currents may be applied, by preventing the bias current from flowing in $R_S$ or R2. Figure 2-12 shows the simplest method for doing this. The disadvantage of this circuit, however, is that $L_A$ shunts $L_X$ thereby greatly affecting the measured value, unless $L_A >> L_X$. The measured value is $L_X/(1 + L_X/L_A)$ (assuming high or equal Q's).

*Also refer to Figure 6-4. R1, R2, and R3 represent bridge circuit components (Fig. 2-8) and represent total resistance for each RANGE switch position. U1, U2, and Rs also represent bridge circuit components. Components connected outside terminals are external networks and bias source (External source, $L_A$, $L_X$, $L_B$, C1, and C2).

The ratio $L_X/L_A$ may be negligible in some cases, particularly if an active circuit replaces $L_A$ (see below). In the circuit of Figure 2-12, C1 blocks the dc from flowing through the ground circuit and $R_S$. The capacitor should have a reactance equal to or smaller than the resistance of R1 (Table 2-3) and a voltage rating greater than $I_{dc}\,R_X$. If $I_{dc}\,R_X > 8$ V, amplifier U1 will be overdriven unless its P+ input is isolated. This can be done by employing the simple R-C network shown in Figure 2-13, where suggested values are C = 0.2 μF and R = 5 MΩ.

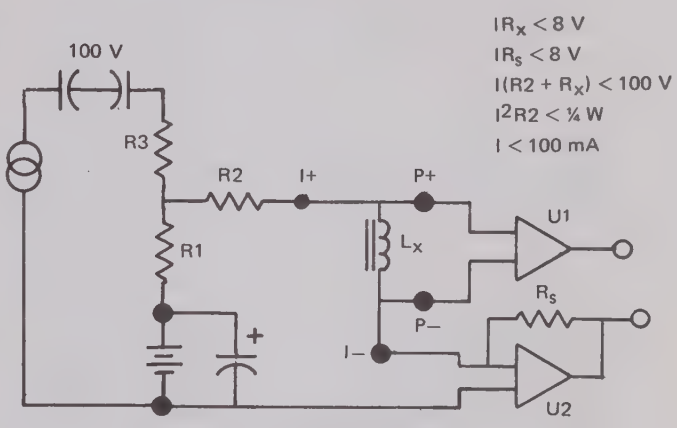



Figure 2-11. Simple bias method.

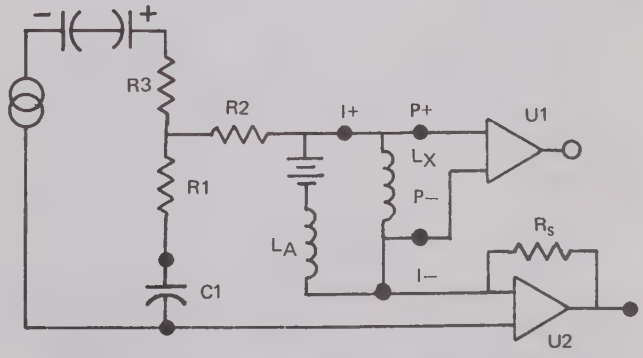



Figure 2-12. Circuit for higher bias currents.

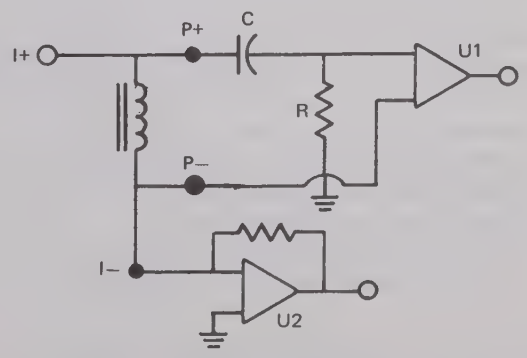



Figure 2-13. Simple active circuit.

The circuit in Figure 2-14 avoids direct shunting of $L_X$ and can usually be used with no noticeable effect on the measured value (except, of course, that due to the dc applied to $L_X$).

In this circuit:

1. $L_B$ should be of a higher inductance than $L_X$, to avoid loading the test signal.
2. $L_A$ should have a reactance about 10 times higher than $R_S$, to avoid errors due to shunting the input of U2.
3. C2 should be chosen so that $\omega^3 L_A L_B C2 >> \omega L_X$.

The expression in item 3 is the effective impedance shunting $L_X$ and can usually be substantially large to avoid any error. For example, if $L_B = L_X$ and $L_A = 10 L_X$, the error is

$$L_X/10\ L_X^2 \omega^2 C \times 100\% = 1/10\omega^2\ L_X C2 \times 100\%.$$

For an $L_X$ of 10 mH and a 1-kHz test frequency, C2 should be greater than 250 $\mu$F. The voltage rating of C2 should be greater than $I_{dc}\ R_A$; where $R_A$ is the dc resistance of $L_A$.

Simple active circuits may be used instead of inductors $L_A$ and $L_B$ shown in Figures 2-12 and 2-14. Figure 2-15 * shows the prototype circuit. The circuit has a low dc voltage drop but a high dc impedance if R1C is very large. The dc drop for the circuit shown is $1.4\ V + I_{dc}\ (R + R1/\beta)$. If $I_{dc}$ is to be large, $\beta$ can easily be made large by using several transistors in the Darlington connection shown in Figures 2-16 and 2-17. The product of the $\beta$'s should be greater than R1/R2.

The addition of each extra transistor increases the DC voltage drop by approximately 0.7 V. Figure 2-18 shows the approximate ac equivalent circuit. In Figure 2-18, R1 shunts the active "inductor." A value of 1 M$\Omega$ for R1 is large enough for any range if the circuit of Figure 2-14 is used. For the circuit of Figure 2-12, R1 must be large enough to avoid an error when shunting $L_X$.

If time constant R1C is too large, the circuit will take a long time to settle. A value of R1C $\cong$ 0.2 s seems a practical value unless measurements are made very slowly. $R_L$ determines the maximum dc current (for a given voltage drop) and also determines the value of the effective inductance (Figure 2-18) if R1C is constant.

Since the effective inductance should be much larger than $L_X$ in the circuit of Figure 2-12, and its reactance should be somewhat larger than $R_S$ in the circuit of Figure 2-14, there is a limit to the current that can be applied to large inductors for a given R1C time constant. However, this current-inductance limit for the circuit in Figure 2-14 is well beyond what is required in most cases (except when active inductors are to be measured).

Figure 2-19 shows a practical circuit for currents up to 0.1 A. The $\beta$ product $\beta_1\ \beta_2\ \beta_3$ should be greater than 20,000.

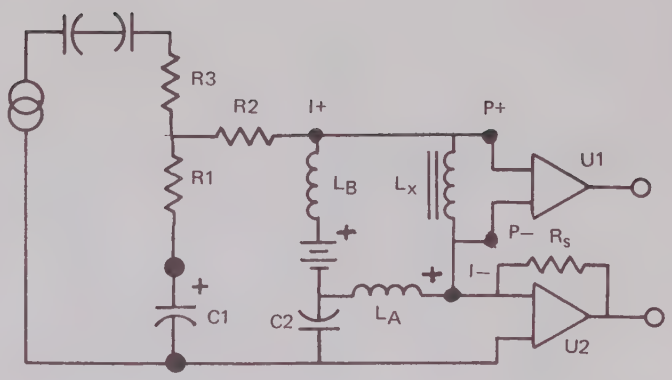



**Figure 2-14. Circuit for higher bias currents, $L_A$ not shunting $L_X$.**

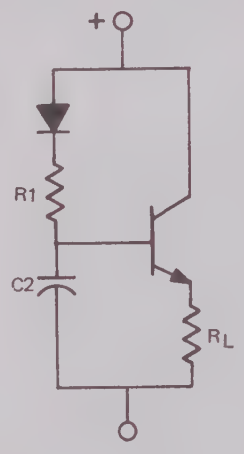



**Figure 2-15. Prototype active circuit.**

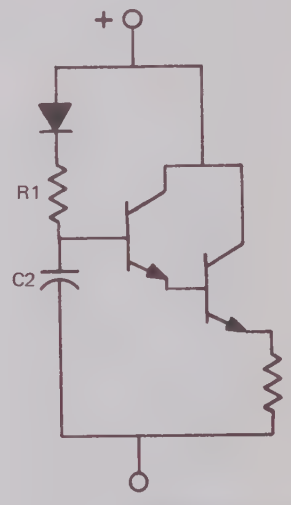



**Figure 2-16. Darlington-connection.**

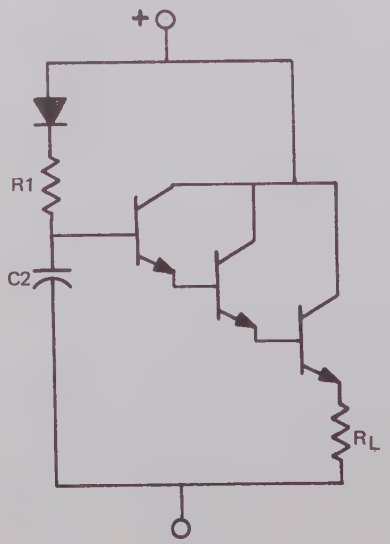



**Figure 2-17. Darlington-connection with additional transistor.**

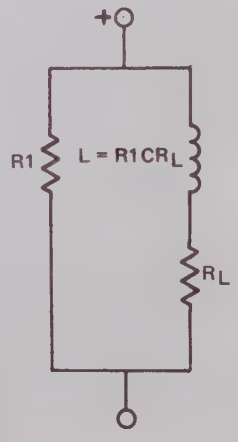



**Figure 2-18. Approximate ac equivalent circuit.**

*Figures 2-15 thru 2-19 represent circuits that replace inductors $L_A$ and $L_B$.

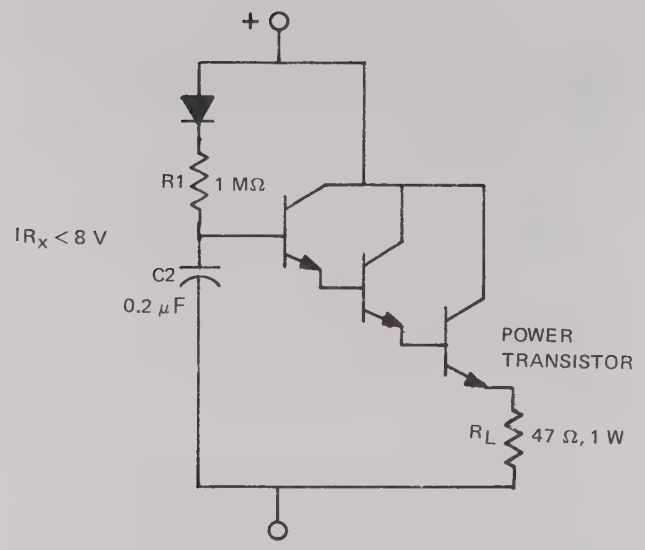



**Figure 2-19. Circuit for currents to 0.1 A.**

## 2.7 POWER-LINE CONNECTION.

The power transformer primary windings can be switched, by means of the five-position switch (Figure 1-2) on the rear panel, to accept a line voltages of 90-110, 104-127, 180-220, 194-236, or 207-253 V. Operation at line frequencies up to 440 Hz, with lower line voltage limits increased by 5%, or down to 45 Hz, with upper limits reduced by 5% is satisfactory. If 50-Hz power is used, it may be necessary to make jumper connections on the instrument's bridge board. Refer to paragraph 3.2 for details. Normally, the instrument is wired for 50-Hz or 60-Hz line frequencies, as specified by the customer. The 1685-9700 series units are wired for a 60-Hz line frequency; the 1685-9800 series are wired for a 50-Hz line frequency.

Connect the 3-wire power cable (P/N 4200-9625) to the line and to the 3-terminal male connector (Figure 1-2) on the rear panel. A 1-A fuse is used at the 2 low voltages. A 0.5-A fuse is used at the 3 higher voltages.

The instrument is fitted with a new design power-connector that is in conformance with the International Electrotechnical Commission publication 320. The 3 flat contacts are surrounded by a cylindrical plastic shroud that eliminates the possibility of electrical shock whenever the power cord is being unplugged from the instrument. In addition, the center ground pin is longer, which means that it mates first and disconnects last, ensuring greater user protection from electric shock.

The panel connector is a standard 3-pin grounding-type, the design of which has been accepted world wide for electronic instrumentation, and is rated for 250 V at 6 A. It also meets requirements of Underwriter's Laboratories in the U.S. and the Canadian Standards Association. The receptacle accepts power cords fitted with the Belden type SPH-386 connector. Its GR part number is 4240-0210.

The associated power cord for use with the new receptacle is GR part No. 4200-9625. It is a 7-ft, 3-wire, 18-gauge unit with connector bodies molded integrally with the jacket. The connector at the power-line end is a stackable hammerhead design that conforms to the "Standard for Grounding Type Attachment Plug Caps and Receptacles," ANSI C73.11-1963.

## 2.8 LINE-VOLTAGE REGULATION.

The accuracy of measurements accomplished with precision electronic test equipment operated from ac line sources can often be seriously degraded by fluctuations in primary input power. Line-voltage variations of ±15% are commonly encountered, even in laboratory environments. Although most modern electronic instruments incorporate some degree of regulation, possible power-source problems should be considered for every instrumentation setup. The use of line-voltage regulators between power lines and the test equipment is recommended as the only sure way to rule out the affects on measurement data of variations in line voltage.

The General Radio Type 1591 Variac® Automatic Voltage Regulator is a compact and inexpensive equipment capable of holding ac line voltage within 0.2% accuracy for input ranges of ±13%. It will assure, for example, that an instrument rated for 100-125 (or 200-250) V can be operated reliably in spite of varying input voltages in the range 85-135 (or 170-270) V. The 1 kVA capacity of the 1591 will handle a rack full of solid-state instrumentation with no distortion of the input waveform. This rugged electromechanical regulator comes in bench or rack-mount versions, each with sockets for standard 2- or 3-wire instrument power cords.

## 2.9 UNPACKING AND INSPECTION

If the shipping carton is damaged, ask that the carrier's agent be present when the instrument is unpacked. Inspect the instrument for damage (scratches, dents, broken knobs, etc.) If the instrument is damaged or fails to meet specifications, notify the carrier and the nearest General Radio field office (see list at back of this manual). Retain the shipping carton and the padding material for the carrier's inspection.

## 2.10 STORAGE AND SHIPMENT

### 2.10.1 Packaging.

To protect valuable electronic equipment during storage or shipment, always use the best packaging methods available. Your General Radio field office can provide packing material such as that used for original factory packaging. Contract packaging companies in many cities can provide dependable custom packaging on short notice. Here are two recommended packaging methods:

*Rubberized Hair.* Cover painted surfaces of instrument with protective wrapping paper. Pack instrument securely

in strong corrugated container (350 lb/sq in. bursting test) with 2-in rubberized hair pads, placed along all surfaces of the instrument. Insert fillers between pads and container to ensure a snug fit. Mark the box "Delicate Instrument" and seal with strong tape or metal bands.

*Excelsior.* Cover painted surfaces of instrument with protective wrapping paper. Pack instrument in strong corrugated container (350 lb/sq in. bursting test) with a layer of excelsior about 6 in. thick, packed firmly against all surfaces of the instrument. Mark the box "Delicate Instrument" and seal with strong tape or metal bands.

**2.10.2 Special Reshipment Instructions.**

There are no special procedures or facilities required for reshipment of the instrument.

# Operation–Section 3


3.1 CONNECTIONS . . . . . 3-1
3.2 LINE VOLTAGE . . . . . 3-4
3.3 RANGE SELECTION . . . . . 3-4
3.4 MAKING MEASUREMENTS . . . . . 3-7
3.5 TYPICAL USES WITH EXTERNAL DEVICES . . . . . 3-9


## 3.1 CONNECTIONS.

### 3.1.1 Power and Data Connections.

Connections for power, external control and for data outputs are descirbed in Section 2. Paragraph 3.2 gives details on synchronizing the instrument's test oscillator with a line voltage that is exactly one-half the test frequency (100- or 120-Hz test frequency).

### 3.1.2 Test Connections.

#### 3.1.2.1 General.

Connections to the unknown may be made using the test cable (supplied), the 1685-P1 Test Fixture (optional), or any other test fixture properly connected.

The test cable furnishes the 5 leads necessary for 2-, 3- or 4-terminal measurements. Four of these leads are shielded (P+, I+, P-, and I-) to prevent errors caused by capacitance between them. These leads are identified by the color of the plug and the cable marking. The *high-potential (HP) lead* is the red lead with the *white band* on it; the *low potential (LP) lead* is the black lead with the *white band.* The high current (HC) lead is the solid red lead; the low current (LC) is the solid black lead. The fifth terminal (on black, low-current lead) is ground, and also guard.

Connections to the unknown component can be made with the banana plugs or with alligator clips on these plugs. For all measurements, the two + (red) plugs should be connected to one side of the unknown and the – (black) plugs to the other side.

Generally, the component can be connected either way, *but when bias is applied,* the + (red) plugs carry the positive dc potential.

A 2-terminal connection can be made by connecting the high current (I+) lead to the high potential lead (P+), and connecting the low current (I–) lead to the low potential (P–), then connecting the P+ and P– leads to the unknown. This may be a desirable connection for measurements in the middle 3 ranges (4-6). However, this will require clipping the leads together.

In general, 4-terminal measurements should be made on impedances under 200 ohms resistance (ranges 1 to 4) and reactance to reduce lead errors. (Refer to para 3.1.2.3). When high impedances, particularly small capacitors, are measured, care should be taken to obtain a repeatable test configuration. (Refer to para. 3.1.2.2), and to shield the unknown from external fields.

Any fixture used and nearby conductive surfaces should be tied to the instrument ground (guard) if possible.

When the test cable is used, it is necessary to apply an additional START pulse to the instrument if the SINGLE-MEASUREMENT mode is used. (Refer to Section 2 for details.)

The 1685-P1 Test Fixture is useful for making rapid connections to small components. It furnishes a 4-terminal connection to the unknown and can make repeatable measurements on low-valued capacitors. It's case is tied to guard (ground), and this connection can be used for further shielding. (Refer to para 3.1.2.2.)

Unless bias is applied, the component under test can be inserted in either direction. When bias is applied, one + (positive) terminal is dc positive.

Depressing the bar on the top front of the -P1 fixture will apply a START pulse to the 1685 for a SINGLE Measurement.

Other fixtures or other test connections can be used with the 1685. The easiest way to make connections is to cut off the banana plugs on the test cable and dress these leads to make the proper permanent connection. The test cables may be lengthened if necessary. Shielded cabling should be used; however, these cables should not have too much capacitance to ground, to avoid loading errors. (Refer to para 3.1.2.3.)

#### 3.1.2.2 Three-Terminal Connections.

In general, 3-terminal connections are made when making measurements of 10 kΩ impedance or greater for ac measurements where stray capacitance may produce undesirable effects. This connection is normally made on 3-terminal components such as impedance standards that have a separate case terminal that should be grounded (guarded) during measurements.

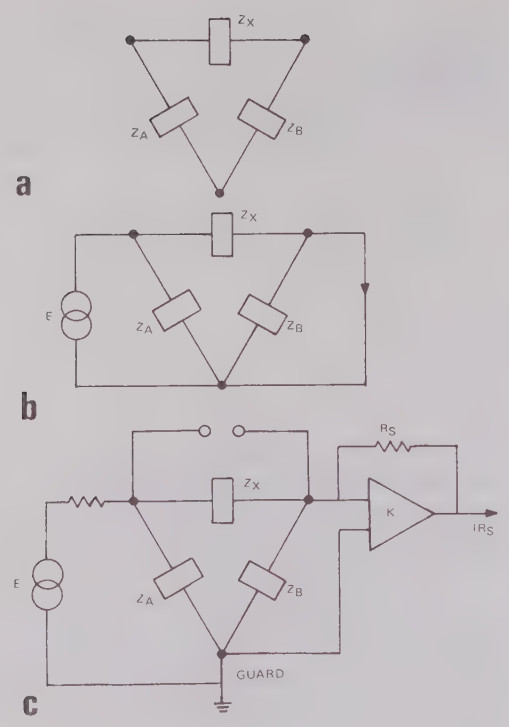



Figure 3-1. Three-terminal network.

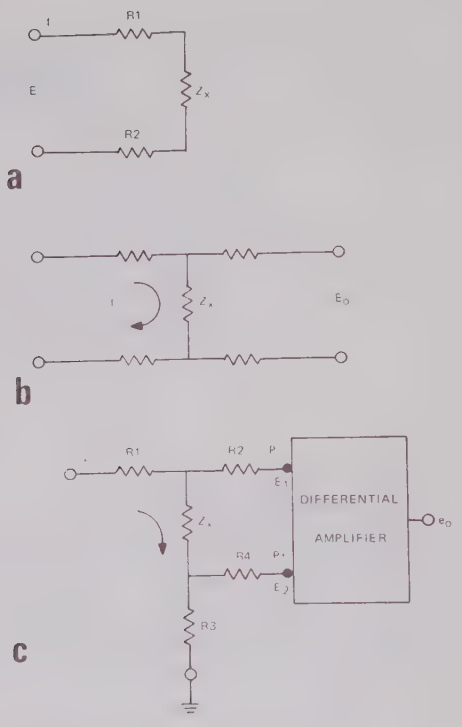



Figure 3-2. Four-terminal network.

Some examples are given in the following paragraphs. If the unknown is a delta impedance connection, as illustrated in Figure 3-1 A, and it is desired to measure $Z_X$, a voltage, E, can be applied (Figure 3-1 B), and the short-circuit output current, $I_O$, can be measured. Then C can be calculated from

$$Z_X = \frac{E}{I_O}.$$

This is one way to make the measurement, and this measurement is not affected by the "stray" impedances, $Z_A$ and $Z_B$, if the voltage source and current detector have zero impedance. The 1685 circuit (Figure 3-1 C) measures the voltage actually applied, E, so that $Z_A$ causes no error directly (However, it loads down the applied signal voltage, making offset voltages in the instrument more critical.)

The input impedance to the current-measurement circuit is $R_S/K$, so that $Z_B$ causes an error of $R_S/KZ_B \times 100\%$. $R_S$ changes with range, with a maximum value of 100 k ohms for ac measurements (ranges 7 and 8). The gain, K, is approximately -j 600 at 1 kHz so that if $Z_B$ is a capacitor of 1000 pF, the error is approximately 0.1% on these two ranges at 1 kHz.

A shielded capacitor has a defined value of capacitance if measured by any 3-terminal system. A small, 2-terminal capacitor will have a measured value that depends on the stray capacitance between its leads and the test connectors. There is no "true" value.

However, repeatable measurements are possible using a fixture of a defined geometry (electrode spacing is specified and the components are centered in it), so that the effect of the stray capacitance is always the same. The capacitance value is generally taken to be the measured value of the capacitor minus the capacitance of the fixture with the capacitor removed. However, different fixtures or different fixture spacings will give different results.

For a capacitor of a specific physical size and shape, the difference between measurements on two different systems will be a constant capacitance difference, independent of the value of the capacitor measured. Therefore, to bring the two measurement systems into agreement, a given low-value capacitor should be measured in both systems and the measurement differences (in pF) used as a correction for further measurements of capacitors of the same physical dimensions.

### 3.1.2.3 Four-terminal Connections.

In general, 4-terminal measurements are used when making measurements under 200 ohms resistance or reactance (ranges 1-4), to reduce lead errors. When an impedance is measured by means of test leads and connectors that have resistance (as illustrated by R1 and R2 in Figure 3-2 A), the measured value will be $Z_X$ + R1 and R2. However, if a current, I, is applied to the 4-terminal network illustrated in Figure 3-2 B, and the output voltage is measured, then

$$Z_X = \frac{E_O}{I},$$

with no lead error.

The 1685 measurement circuit (Figure 3-2 C) uses the type circuit described above, with a differential amplifier to obtain the output voltage $E_1 - E_2$. This amplifier has high input impedance so that R1, R2 and R4 have no effect. The voltage drop, IR3, however, causes a common mode voltage which will cause an error of

$$\frac{\text{R3}}{\text{common mode rejection factor}} \text{ ohms.}$$

For DC, the common mode rejection factor is adjusted to be greater than 1000, so that if R3 equals 1 Ω there is an error of less than 1 mΩ. (Note that voltage IR3 must be less than 1 V for proper operation, which means that R3 must be less than 5 ohms on ranges 1 and 2.)

When measuring a 4-terminal resistor, the defined resistance is that between the two lead junctions, A and A', as illustrated in Figure 3-3 A. Therefore, when making a 4-terminal connection to a resistor by means of test leads, the measured resistance is that between the two innermost measurement connections (Figure 3-3 B). A 2-terminal decade box can be measured with good repeatability by using the arrangement of Figure 3-3 C; GR 1440-Type resistors can be measured using the arrangement shown in Figure 3-3 D.

Usually, I+ and P+ may be interchanged, as can P– and I–.

### 3.1.2.4 Connection to Low-value Inductors.

Measurements on low valued inductors are subject to errors due to lead self-inductance and mutual inductance.

A two terminal measurement as shown in Figure 3-4 A would indicate $L_X + \ell_1 + \ell_2 - 2M_{12}$ where $\ell_1$ and $\ell_2$ are lead self inductances and $M_{12}$ the mutual inductance between them. To keep the error terms small, the leads should be short and they should be twisted or concentric to increase the mutual inductance so that 2M is nearly equal to $\ell_1 + \ell_2$. (It can never be equal to or greater than $\ell_1 + \ell_2$.)

The self inductance error may be removed by making a four-terminal measurement, with connections right at the

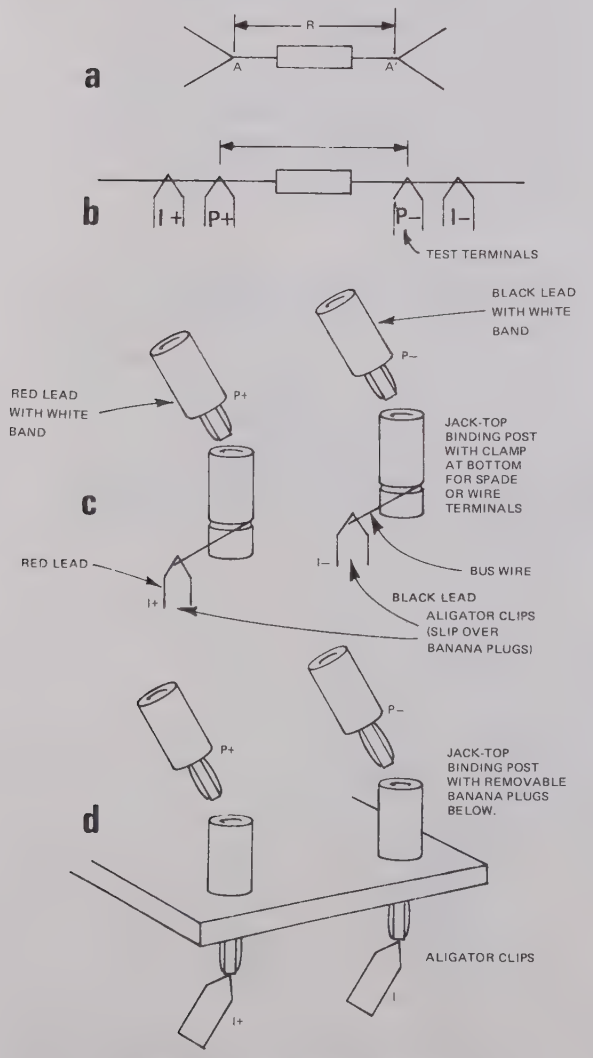



**Figure 3-3. Four-terminal connection.**

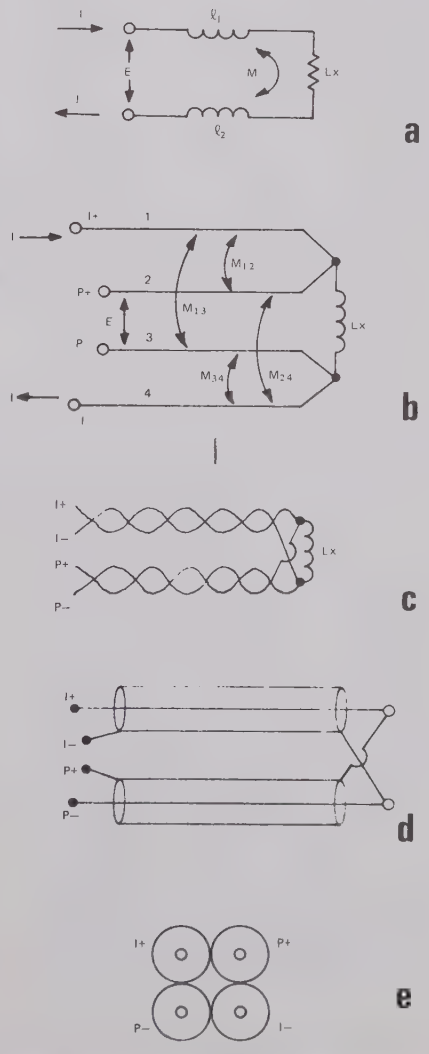



**Figure 3-4. Connections to low-valued inductors.**

inductor terminals. However, now mutual inductance between the current and potential leads (Figure 3-4 B) gives a measured value of

$$L_X + M_{12} + M_{34} - M_{13} - M_{24}.$$

Note that the error can be positive or negative, depending on the positions of the wires which determine the mutual inductance values.

This error may be reduced by making the mutual inductances small or making them equal. One way to greatly reduce this error is to twist the potential (P) leads together and twist the current (I) leads together (Figure 3-4C). (The mutual inductances $M_{14}$ and $M_{23}$ do not affect the measurement.) This not only reduces the undesired mutual inductances but also gives a high degree of symmetry so that they cancel well. The shielded lead arrangement of Figure 3-4 D is even better, for there is no magnetic field outside the shields. The shielded test leads used in the 1685 reduce this error by using a lead arrangement with a cross-section shown in Figure 3-4 E, which keeps the mutual inductances symmetrical so that they cancel.

The above precautions still leave errors caused by various mutual inductances at the actual connection and between the leads and the coil. There is really no "true" value. In order to get repeatability, the best method is to replace the inductor with a piece of wire of the same length as the inductor and subtract the measured value of this from the measured value of the inductor. This is particularly easy to do with the 1685-P1 test fixture.

## 3.2 LINE AND TEST FREQUENCIES.

The instrument is shipped connected for a 100- or 120-Hz test frequency, as specified by the customer*. The instrument's test frequency oscillator can furnish either a 120-Hz or a 100-Hz frequency (in addition to the 1-kHz test frequency). The 100-Hz frequency is obtained by rewiring (removing) the shorting wires across R144 and R279 on the bridge board, as noted in Figure 6-4. Also, if a 100-Hz test frequency is being used, the D-Q circuit terminals noted in Figure 6-4 are short-circuit together otherwise the D-Q circuit will not make a proper measurement. If the desired oscillator frequency is exactly twice that of the line frequency being used (50 or 60 Hz), the synchronization signal from the power supply is connected to wire-tie 7 (WT7). Refer to Figures 6-4, 6-14, and 5-1. If not, this synchronization signal from the power supply bridge assembly should be rewired (disconnected), in which case the test frequency will be accurate to approximately ±2%.

## 3.3 PARAMETER AND RANGE SELECTION.

### 3.3.1 Parameter Selection.

Set the PARAMETER switch to the function to be measured: R at DC, or C or L at 120 Hz or 1 kHz. The choice of test frequency is often specified for inductors and capacitors. If not, the choice depends to some degree on the value to be measured.

Measurements at 1 kHz extend to lower ranges and 120 Hz to higher ones. (Refer to Table 3-1 and Figures 3-5 to 3-9). Note that 1-kHz measurements are more accurate. However, a 120-Hz measurement can be more meaningful; for example, a power choke may be near resonance at 1 kHz.

### 3.3.2 Range Selection.

Table 3-1 lists the instrument ranges. The maximum reading is 19999 for DC and 1 kHz, and 1999 for 120- (or 100-) Hz operation. The table gives the maximum reading for each range. Figures 3-5 to 3-9 are accuracy charts for the C, R and L measurements.

*The 1685-9700 series instruments are wired for a 60-Hz line frequency and 120-Hz test frequency; the 1685-9800 series are wired for a 50-Hz line frequency and 100-Hz test frequency. A change from one frequency to another can be made by making the changes noted above.

Table 3-1

RANGES AND RLC FULL-SCALE READINGS AND ACCURACY AND VOLTAGE MULTIPLIERS

| Range Switch Position | C (1KHz) M † | | C (120Hz) M † | | RDC M † | | L (120Hz) M † | | L (1KHz) M† | | Volt Mul. A † |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | (1999.9μF* | 10) | 19.99 mF** | 4 | (199.99mΩ* | 20) | (199.9μH* | 10) | (19.999μH* | 10) | 0.1 |
| 2 | 199.99μF | 3 | 1.999mF | 2 | 1999.9mΩ | 3 | 1.999mH | 2 | 199.99μH | 3 | 0.1 |
| 3 | 19.999μF | 1 | 199.9μF | 1 | 19.999Ω | 1 | 19.99mH | 1 | 1999.9μH | 1 | 1 |
| 4 | 1999.9nF | 1 | 19.99μF | 1 | 199.99Ω | 1 | 199.9mH | 1 | 19.999mH | 1 | 1 |
| 5 | 199.99nF | 1 | 1.999μF | 1 | 1999.9Ω | 1 | 1.999H | 1 | 199.99mH | 1 | 1 |
| 6 | 19.999nF | 1 | 199.9nF | 1 | 19.999kΩ | 1 | 19.99H | 1 | 1999.9mH | 1 | 1 |
| 7 | 1999.9pF | 2 | 19.99nF | 1 | 199.99kΩ | 1 | 199.9H | 1 | 19.999H | 1 | 1 |
| 8 | 199.99pF | 3 | 1.999nF | 2 | 1999.9kΩ | 3 | 1.999kH | 2 | 199.99H | 3 | 5 |
| 9 | —— | | —— | | 19.999MΩ | 5 | —— | | —— | | 5 |

* Not Recommended
** Extends to 0.1F at reduced accuracy
†See specifications for multiplier definitions, Also see para 3.3.2.

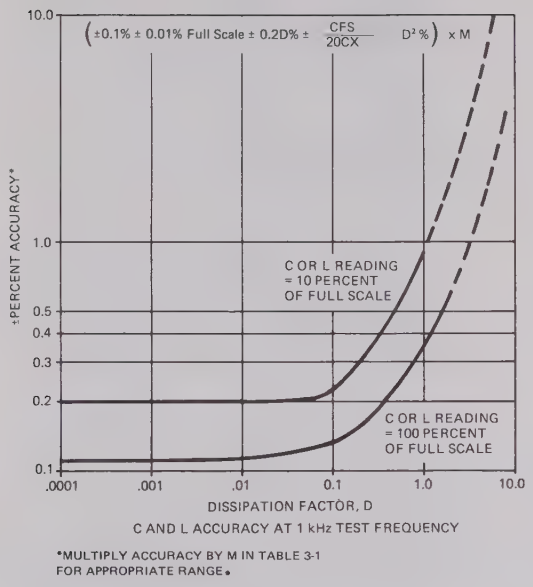



**Figure 3-5. C and L accuracy as a function of dissipation factor (test frequency 1 kHz).**

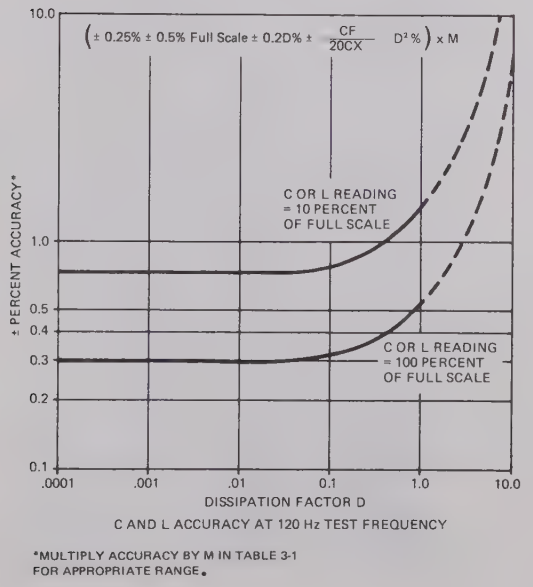



**Figure 3-6. C and L accuracy as a function of dissipation factor (test frequency 120 Hz).**

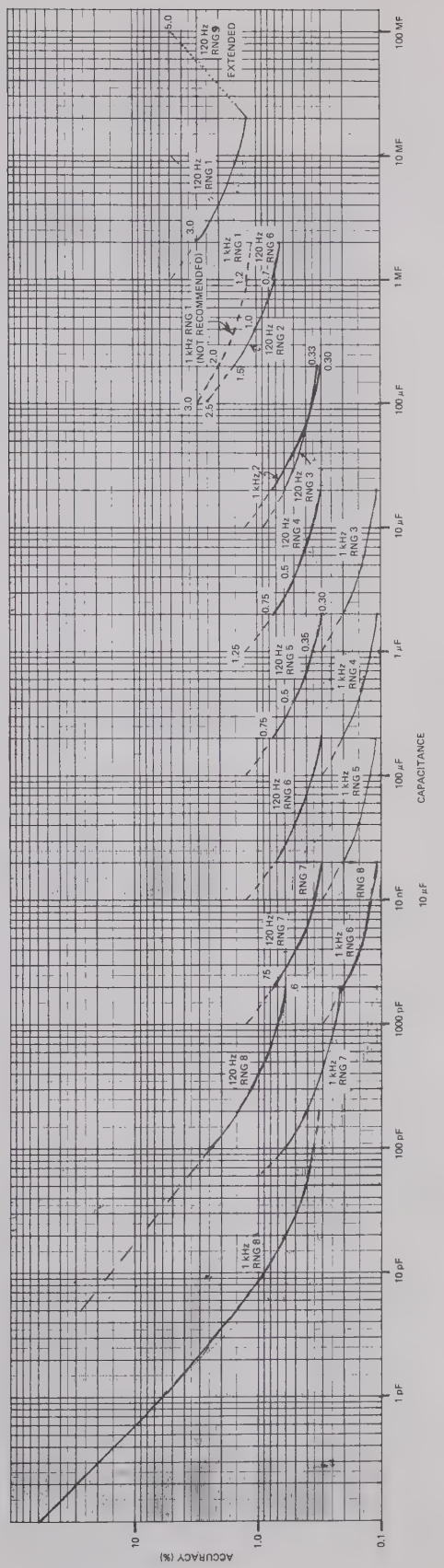



**Figure 3-7. Capacitance measurement accuracy chart.**

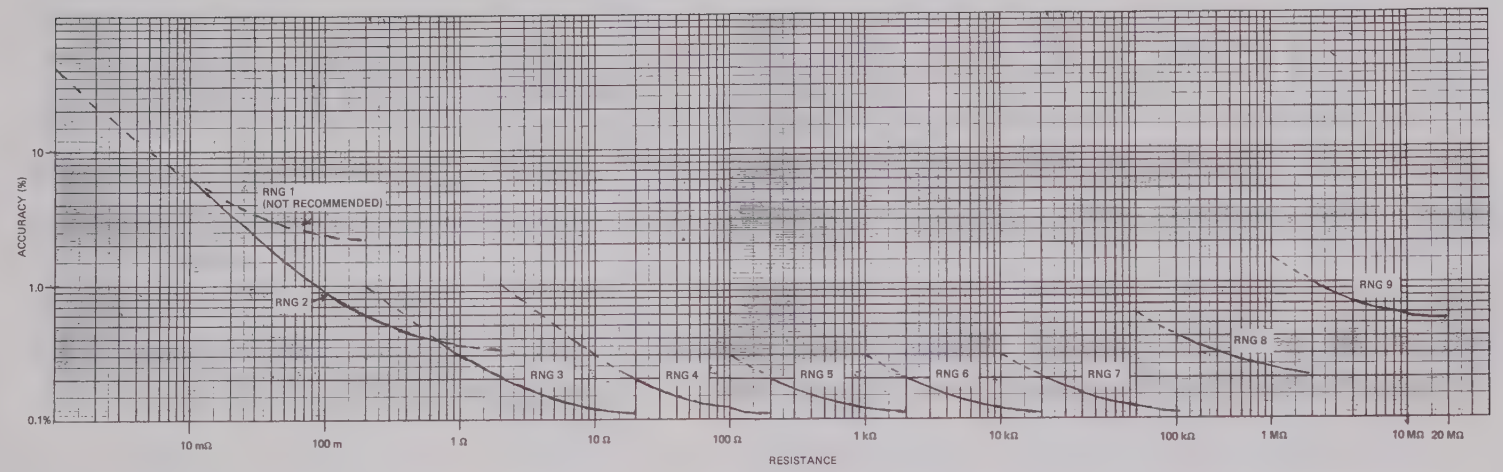



**Figure 3-8. Resistance measurement accuracy chart.**

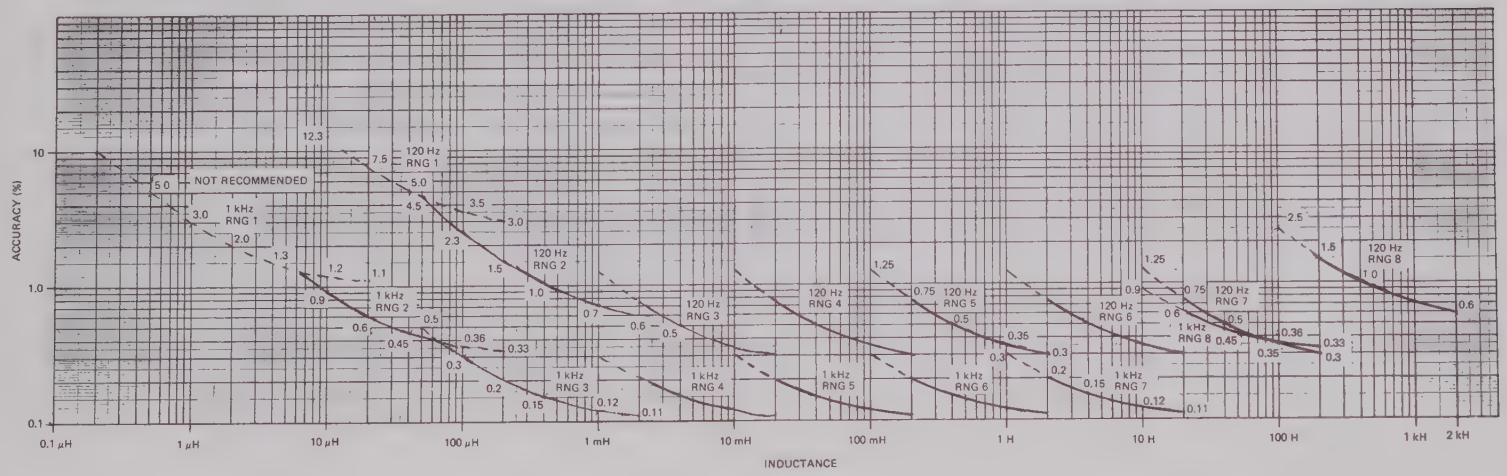



**Figure 3-9. Inductance measurement accuracy chart.**

The proper measurement range is selected by turning the RANGE switch in the direction indicated by the arrows. Turn the switch until the lights extinguish. This sets the range so that the measurement result will be approximately between full scale and 1/10th of full scale, for best resolution and accuracy.

The exact determination of very near full scale and 1/10th of full scale will depend on the measurement value displayed, which for best resolution should be between 2000 and 19999 for DC and 1 kHz, and 200 and 1999 for 120-Hz test frequency. An arrow indicator may indicate that a measurement of 19995, for example, should be made on the next range, when in fact the measurement is a valid measurement.

The range must be increased, however, when a display reads E, indicating the display has exceeded a 19999 or 1999 reading.

On the lowest recommended ranges, the lights will be out even though the reading will be less than 1/10th full scale.

As noted in Table 3-1, range 1 is not recommended for most component values within the indicated measurement range because of poor accuracy. However, Range 1 is recommended for 120-Hz capacitance measurements. It can be used to measure beyond its nominal range up to 100 mF at 120 Hz at a reduced measurement accuracy, even though the E indication is displayed. The added error is

$$\pm \frac{C_X}{1F} \times 50\%.$$

Other components can be measured using this range, if desired (although not recommended). Range 1, however, is useful for measuring differences in resistance values. Except for the capacitance measurement at 120 Hz, the range indicator lamps will illuminate for all other measurements on range 1.

Range 9 can only be used for resistance measurements of up to 19.999 MΩ. Range 9 should not be used for any other measurements; the meter will not operate in this measurement range. Note that the range indicator lamps *will not* operate in range 9 for the resistance measurement. For blanked-out ranges, an illuminated arrow-indicator lamp will denote that the range is not valid.

The accuracy for each range can be determined from the data in "Specifications" at the front of the manual. The multiplier factor given in Table 3-1 is the factor that the accuracy equation should be multiplied to obtain the measurement accuracy for each range. Figures 3-5 to 3-9 are accuracy charts showing the accuracy for each parameter measurement range.

The voltage multiplier in Table 3-1 is the multiplier to be used to determine the maximum voltage applied to the part under test. This is

A X 1 V rms, for AC
A X 2 V max, for DC.

## 3.4 MAKING MEASUREMENTS

### 3.4.1 Parameter Measurements.

To make a measurement:

a. Make the test-lead or fixture connections to the instrument as described in para. 3.1. Refer to Section 2 for details on operating the instrument under external control and/or with external devices.

**WARNING**

**Electrical energy stored in charged capacitors can be dangerous to the operator of the Meter. Full bias voltage appears on test-lead and test-fixture terminals and the leads of the component under test when an external bias source is connected and the CAPACITOR BIAS Switch is set to EXT.**
**Capacitors remain charged after measurement. The user must follow safe procedures to assure proper discharge of measured capacitors.**
**For safety reasons, all personnel operating the Meter must be aware of the potential hazard involved in external biasing of capacitors and inductors.**
**Do not leave the Meter unattended with external bias applied.**

b. Set the PARAMETER switches for the type of measurement desired. If capacitance is being measured and the capacitor requires biasing, set the CAPACITOR BIAS switch to INTERNAL or EXTERNAL BIAS, as applicable. Refer to para 2.6 for details on applying external bias to the instrument. *Make sure* that CAPACITOR BIAS switch is set to OFF when measuring resistors. For biasing inductors, refer to para 2.6.2.

c. Turn on the meter by setting the START switch to ON.

d. Connect a component to the test leads or install it on the test fixture and adjust the MODE switch for the desired rate of measurement operation (0.25 to 10 s), if repetitive operations are desired. If using the test fixture or an external device to initiate measurements, the MODE switch can be set to SINGLE. The -P1 test fixture initiates a measurement when its cover bar is pressed by the operator. (Refer to Section 2 for details on using other external devices to initiate a measurement via the rear-panel MEASUREMENT DATA connector.)

e. Set the RANGE switch, as applicable, to the desired range. If the comparator option is being used, set the HIGH- and/or LOW-LIMIT digit-switches to the desired setting. (Note that comparator makes a low-limit comparison before it makes the high-limit comparison, regardless of the low-limit switch settings and lights.)

f. Observe the RANGE lamps during the measurement and adjust the RANGE control as necessary. Refer to the previous paragraph for details on the range controls and indicators. During a meausrement, the small, red indicator lamp below the display illuminates. When the measurement is completed the lamp extinguishes.

g. When the proper range is established, set the instrument for external starting or repetitive measurements. The measured value of a unknown remains displayed during the measurement of the next component. When the next measurement is completed, the display will read the new measurement.

In the REPETITIVE mode of operation, the measurement time is determined by the setting of the MEASUREMENTS MODE switch. The actual measurement may be completed before the time established by the switch, but the new value will *not* be displayed (or available for recording) until the established time.

In the SINGLE mode, the external device establishes the measurement time by providing the "start" signal. In addition to establishing measurement time, this feature can be used to allow recording devices ample time to record measurements, when the data-output option is available.

The measurement units (pF, mH, etc.) are not available for recording. The units are displayed on the range switch, however, and the user can note on the recording media, if desired.

### 3.4.2 D-Q Measurements.

The range indicator lamps beside the D-Q dial indicate by means of illuminated arrows if the D or Q measurements are above or below the setting on the dial. The red arrow indicates a high D; the green arrow a GO condition. If it is desired to obtain the exact reading, turn the dial to the position where indicators alternately illuminate or both remain lit.

If the comparator option is being used and the D lamp lights during a measurement, it indicates that the D of the unknown is higher (or the Q is lower) than the D value set on the D-Q dial.

### 3.4.3 Charging and Discharging Times for Capacitors

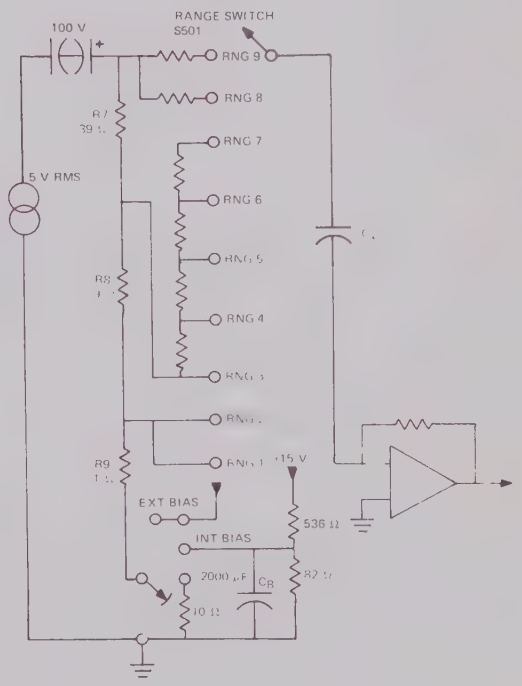
CAUTION

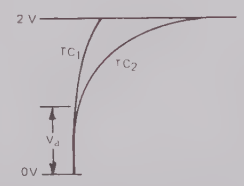
Do not use the meter to discharge capacitors biased with a higher external voltage. This may damage the meter. When an external voltage higher than 2 V is used to bias capacitors, do not turn the CAPACITOR BIAS switch to OFF while the charged capacitor is connected to the meter. The user should furnish a discharge switch or other means for discharging externally biased capacitors. Do not use more than 100 V external bias.

WARNING

**Be careful when handling charged capacitors biased by a higher external voltage. Provide a warning if it is necessary to leave (not recommended) the meter unattended while a high external voltage is applied to the meter. The bias voltage is present at the test terminals and at the test fixture terminals when the switch is set to EXTERNAL.**

*Charging Time using Internal Bias.* Figure 3-10 shows the bias supply switch configuration, with an unknown capacitor ($C_X$) under test in the circuit. The unknown is connected to the internal bias supply when the CAPACITOR BIAS switch is set to INTERNAL 2 V or when the switch is already set to INTERNAL 2 V and the unknown is connected to the test terminals. For capacitors under 20 $\mu$F, the charging time constant is less than 3 ms. The voltage will be within 5% of the final value in a period of three time constants.




$TC_1$ = CHARGING TIME CONSTANT IF $C_B$ NOT APPRECIABLY DISCHARGED ($C_x < 20\ \mu F$)

$TC_1$ = < 3ms

$TC_2$ = CHARGING TIME CONSTANT OF $C_B$ AND $C_x$

$\cong 72\ \Omega\ (C_B + C_x) = 72\ (2000\ \mu F + C_x)$

$$V_a = 2\ V\ \frac{C_B}{C_B + C_x} = 2\ V\ \frac{2000\ \mu F}{2000\ \mu F + C_x}$$

NOTE

$V_a < 1.98$ V IF $C_x < 20\ \mu F$, SO THAT $TC_2$ NOT IMPORTANT FOR VALUES UNDER 20 $\mu$F. IF $C_x = 2000\ \mu F$, $V_a = 1$ V.

**Figure 3-10. Capacitor charging times.**

Figure 3-10 also shows an approximation of the charging time ($TC_2$) when a capacitor greater than 20 $\mu$F is connected to the bias supply. As shown, the charging time using the internal bias is $TC_2 = 72 (C_x + 2000)$. The minimum time is 0.144 s, and the maximum can be 1.5s for a 20,000-$\mu$F capacitor. The *charging time, $TC_2$, is unimportant* for values under 20 $\mu$F.

*Discharging Internally Biased Capacitors.* Internally biased capacitors can be discharged by means of the meter by slowly switching the CAPACITOR BIAS switch to OFF. The switch connects to the 10-$\Omega$ arm before connecting the unknown to ground. The time is less than $C_x$ (11$\Omega$) + 3 ms, assuming the switch is turned off slowly compared to approximately 20 ms; that is, for example, 20,000 $\mu$F (11 $\Omega$) +3 ms = 25 ms.

*Charging Time Using External Bias.* The time it takes to charge externally biased capacitors depends on the bias supply used. If the supply has an "indefinite bus," that is, zero resistance, then $TC_2$ (see Figure 3-10) will be less than 3 ms, up to 2000 $\mu$F, and less than 30 ms at 20,000 $\mu$F. (or, for instance, $C_x$ x 1$\Omega$ + 3ms).

If the supply has a capacitor output as shown in Figure 3-11, then the charge time would be the same as that of that of the internal supply, except $TC_2$ would become RC. Similarly, $V_a = C/C+C_x$ x supply voltage. If the supply is current-limited, $t = C_xV/I_{MAX}$ will be added to the charging time. (Refer to Section 2 for details on external bias power supplies.)

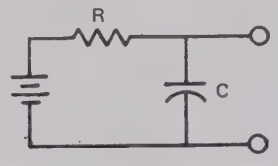



**Figure 3-11. Supply with capacitor output.**

*Discharging Externally Biased Capacitors.* Do not set the CAPACITOR BIAS switch to OFF while an externally charged capacitor is connected to the meter. This may damage the meter.

The user should supply a switch or device to discharge the capacitors, making sure the resistor used is adequate to handle the charge held on the capacitor. Also observe the warning noted at the beginning of this paragraph.

### 3.5 TYPICAL USES WITH EXTERNAL DEVICES.

Figure 3-12 is a block diagram application drawing illustrating the use of the 1685 rear-panel data and control signals in conjunction with external equipment. A digital printer is shown connected to the rear-panel connector of the main instrument, and a mechanical parts handler is shown connected to the rear-panel connector of the limit option "A" board.

The digital printer, in addition to the BCD and decimal point data input lines, has two additional input lines (for control), plus one output line. One of these control inputs

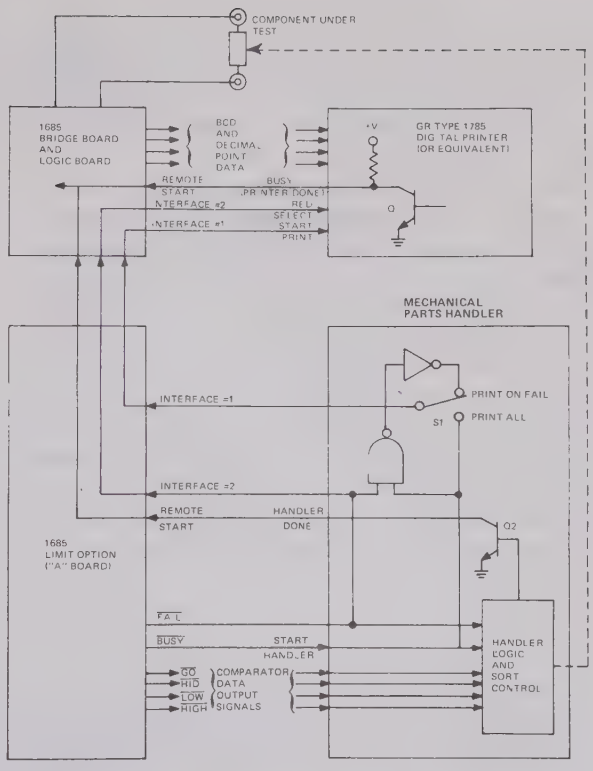



**Figure 3-12. Comparator and external device application.**

is the PRINT START command and the other is the RED SELECT line. The latter, when activated, causes the printer to print out in red (rather than black). The one printer output line, designated $\overline{\text{BUSY}}$ at the printer, is a line that goes high at the end of the print operation, signifying that the printer has finished printing the measurement value (PRINTER DONE).

The mechanical handler is a device designed (or purchased) by the user for use in an incoming inspection operation where many parts of the same value are to be measured and checked against the comparator high- and low-limit values. The handler is shown receiving the comparator output data signals, as well as two control signals, $\overline{\text{BUSY}}$ and $\overline{\text{FAIL}}$.

Use of the REMOTE START, INTERFACE #1, INTERFACE #2, $\overline{\text{BUSY}}$, and $\overline{\text{FAIL}}$ lines available at the rear of the 1685 are clearly illustrated. Switch S1 in the handler, labelled PRINT ALL/PRINT ON FAIL is strictly an optional feature.

The sequence of operations for the configuration shown would be as follows:

First, all BCD and decimal point data is produced on the 1685 logic board and impressed upon the data output lines. The $\overline{\text{FAIL}}$, $\overline{\text{GO}}$, $\overline{\text{HID}}$, $\overline{\text{LOW}}$, and $\overline{\text{HIGH}}$ signals are then produced on the limit option "A" board.

Then signal $\overline{\text{BUSY}}$ is issued from the limit option "A" board. This signal is used to start both the handler and the printer. The handler proceeds to mark or to sort the just-

measured component into the correct line, and to begin moving a new component mechanically into place while the printer proceeds to print out the value of the component, depending upon the position of switch S1 and the state of the $\overline{\text{FAIL}}$ line from the "A" board.

When the printer has completed its operation, it turns off transistor Q1. And when the handler has finished its operation, it turns off transistor Q2. Since the printer and the handler operate at independent rates, transistors Q1 and Q2 will shut off at different times. Therefore, the last one to turn off is the one that produces the low-to-high logic transition on the REMOTE START line required to initiate a new measurement by the 1685.

Having initiated a new 1685 measurement cycle, the above sequence of operation is then automatically repeated. Note that the MODE switch on the front panel of the 1685 must be in its SINGLE MEASUREMENT position in this application.

An alternative configuration employing a multiple limit comparator in place of the Limit Option module (good for single high- and low-limits only) is also possible, so that components can be sorted into ±20%, ±10%, ±5%, ±1%, etc. categories, as desired. All of the signals required to run such a comparator are available from the 1685 rear-panel connector. Figure 3-13 is a block diagram showing this configuration.

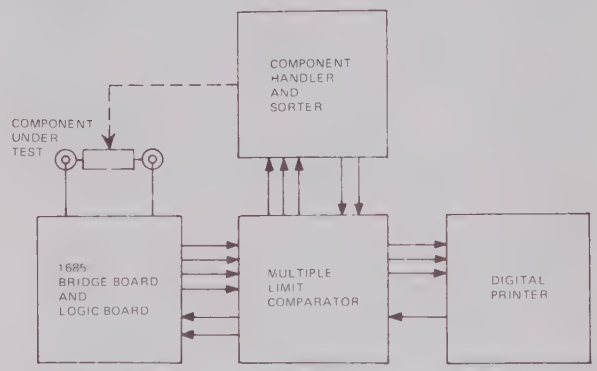



**Figure 3-13. External multiple-limit comparator application.**

## IMPEDANCE MEASUREMENTS

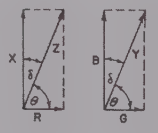
### D AND Q

An important characteristic of an inductor or a capacitor, and often of a resistor, is the ratio of resistance to reactance or of conductance to susceptance. The ratio is called dissipation factor, D, and its reciprocal is storage factor, Q. These terms are defined in Figure 1 in terms of phase angle $\theta$ and loss angle $\delta$. Dissipation factor is directly proportional to energy dissipated, and storage factor to energy stored, per cycle. Power factor (cos $\theta$ or sin $\delta$) differs from dissipation factor by less than 1% when their magnitudes are less than 0.1.

In Figure 1, R and X are series resistance and reactance, and G and B are parallel conductance and susceptance, of the impedance or admittance involved.

Dissipation factor, D, which varies directly with power loss, is commonly used for capacitors. Storage factor, Q, is more often used for inductors because it is a measure of the voltage step-up in a tuned circuit. Q is also used for resistors, in which case it is usually very small.

Most General Radio capacitance and inductance bridges also measure D or Q.




$$D = \cot\theta = \frac{R}{X} = \frac{G}{B} = \frac{1}{Q} = \tan\delta$$

$$\text{Power Factor} = \cos\theta = \frac{R}{Z}$$

$$Q = \tan\theta = \frac{X}{R} = \frac{B}{G} = \frac{1}{D} = \cot\delta$$

**Figure 1. Vector diagram showing the relations between factors D and Q, and angles $\theta$ and $\delta$**

### SERIES AND PARALLEL COMPONENTS

Many GR impedance bridges give the user the option of measuring the unknown in terms of either its series or parallel equivalents. The choice is a matter of convenience for the problem at hand. Since the distinction between series and parallel equivalents is sometimes overlooked in texts, we will briefly summarize the relationships here.

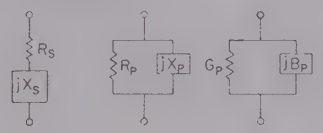



**Figure 2. Series and parallel components of impedance.**

Regardless of physical configuration, every impedance can be expressed, for any given frequency, as either a series or a parallel combination of resistance and reactance, as shown in Figure 2. The relations between the elements of Figure 2 are:

$$R_P = \frac{1}{G_P} = \frac{R_S^2 + X_S^2}{R_S} = R_S(1 + Q^2)$$

$$X_P = \frac{1}{B_P} = \frac{R_S^2 + X_S^2}{X_S} = X_S(1 + D^2)$$

In terms of series and parallel capacitive and inductive reactances, these relations become:

$$C_P = C_S\left(\frac{1}{1 + D^2}\right)$$

$$C_S = C_P(1 + D^2)$$

$$L_P = L_S\left(1 + \frac{1}{Q^2}\right)$$

$$L_S = L_P\left(\frac{Q^2}{1 + Q^2}\right)$$

Where:

$$Q = \frac{X_S}{R_S} = \frac{R_P}{X_P} = \frac{B_P}{G_P} = \frac{\omega L_S}{R_S} = \frac{R_P}{\omega L_P} = \frac{1}{D}$$

and

$$D = \frac{1}{Q} = \frac{R_S}{X_S} = \frac{X_P}{R_P} = \frac{G_P}{B_P} = \omega R_S C_S = \frac{1}{\omega R_P C_P} = \frac{1}{Q}$$

If Q is 10 or more (or if D is 0.1 or less), the difference between series and parallel reactance is no more than 1%. For very low Q's or high D's, however, the difference is substantial; when $Q = 1$, $X_P$ is twice $X_S$. If there were no losses in the reactive elements (i.e., $D = 0$), $X_S$ and $X_P$ would be equal.

# Theory–Section 4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4.2 CIRCUIT DESCRIPTIONS . . . . . 4-2
4.3 LIMIT COMPARATOR . . . . . 4-17
4.4 POWER SUPPLY . . . . . 4-21


## 4.1 INTRODUCTION

### 4.1.1 General.

The 1685 Digital Impedance Meter measures series inductance and capacitance at two frequencies: 120 Hz and 1 kHz; dc resistance; dissipation factor, D, of capacitors; and storage factor, Q, for inductors. With the front-panel MODE switch, the 1685 can be controlled for measurement rates of 0.25 s to 10 s. The front-panel digital readout meter gives readings of C, R, and L, and the front-panel dial reads both D and Q (D = 1/Q). A limit-comparison option is available for making C, R, and L high- and low-limit value comparisons, furnishing pass-fail indications as well as indicating the limit(s) the measured value exceeds.

Figure 4-1 is a block diagram of the meter. The meter is comprised of an amplifier, or "half-bridge," circuit and an AC-DC ratio meter capable of high accuracy with good noise immunity. The ratio meter is a combination of a dual-slope integrator and an integrating phase-sensitive detector. The same circuit is used for AC and DC ratios. The bridge and ratio meter circuitry is mounted on the 1685-4720 bridge board on the floor of the instrument. A logic board (P/N 1685-4700), located above the bridge board, on hinges that allow easy access to board components, furnishes all control and counting circuits for the ratio meter.

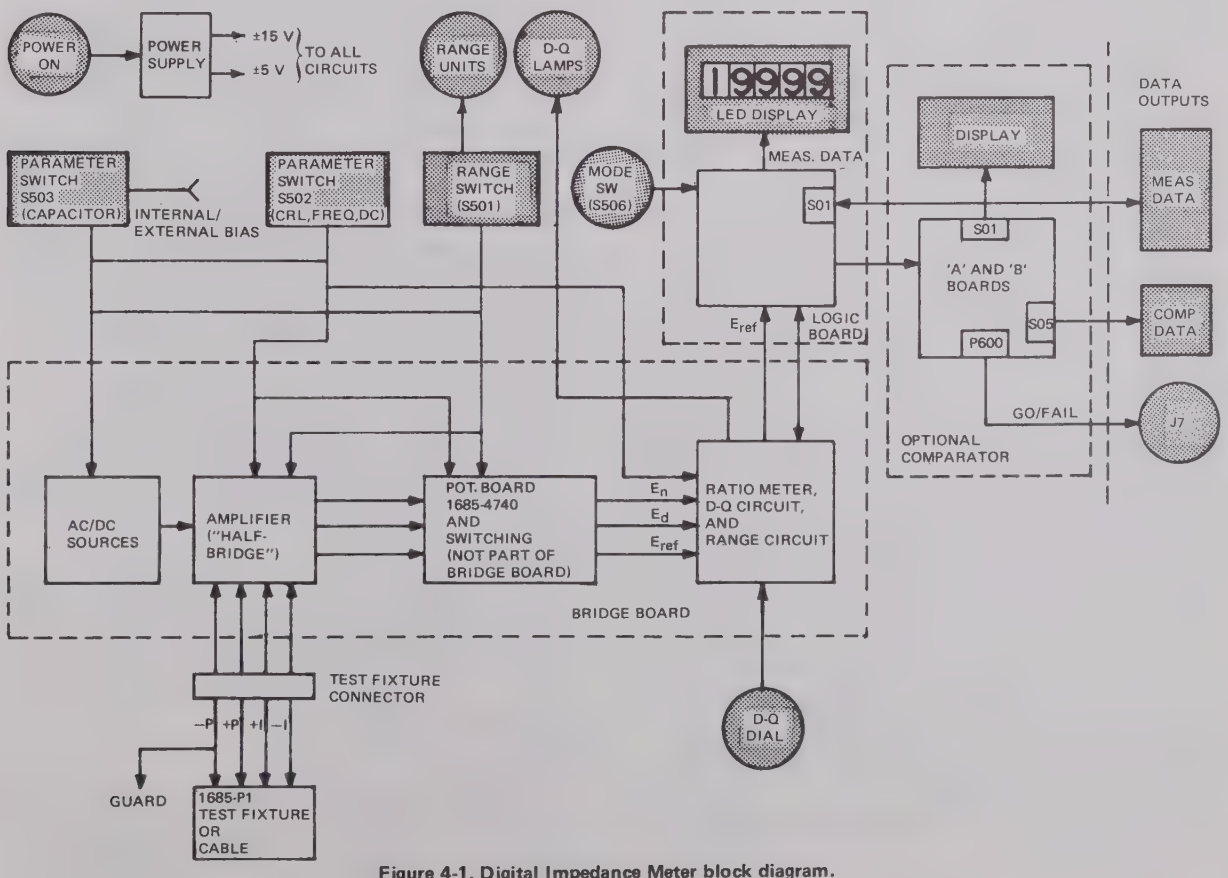



**Figure 4-1. Digital Impedance Meter block diagram.**

A power supply board (P/N 1685-4730) furnishes all DC voltages to all the circuit boards, including the internal 2-V bias voltage for capacitors under test. The board is at the left front of the instrument, under a metal cover.

The bridge board contains:

1. A Wien-bridge oscillator that produces a 1-kHz or 120- (or 100-) Hz, 5-V rms, maximum, a-c test signal and the reference signal for resistance measurements.

2. A linear measurement circuit that has two arms, or networks. One of these detects the voltage across the part under test. The other has a ratio arm resistor of various decade values, selected by the RANGE switch, that produces a voltage directly proportional to the current through the part under test. For ac measurements the signals are phase-shifted so that the outputs are inphase (actually $-E_n$ and $E_d$ are exactly 180° out of phase) when a pure reactance is being measured.

3. A ratio meter circuit that comprises a main AC-DC integrator and comparator, an auxiliary integrator, and a dual-slope integrator and comparator.

4. A circuit for detecting high and low dissipation — factor values for capacitors and high and low storage factor, Q, values for inductors. The circuit is used in conjunction with the front-panel D-Q dial, which sets the D-Q limit, and with the D-Q lights that indicate if the limit has been exceeded.

5. A range-finding circuit that detects overrange and underrange conditions and indicates these by illuminating the lamps associated with the front-panel RANGE switch.

There is a small potentiometer board (P/N 1685-4740) mounted on the back of PARAMETER switch S502. This board contains adjustable resistors used to calibrate the various bridge configurations and to align the D-Q measurement circuit. The resistors are factory adjusted.

The logic board contains:

1. A circuit that determines, by means of a one-shot flip-flop and the front-panel MODE switch, the time and mode of measurement (single or repetitive).

2. A circuit that produces 20 or 200 burst (BST) pulses for the ratio meter. The pulses are derived from the reference signal.

3. A circuit that produces the correction signal, $\overline{CTN}$, if the main integrator output exceeds the established threshold.

4. A counter comprised of 4 decade stages and one flip-flop. The counter counts BST pulses; strobes denominator ($\overline{CTN}$) pulses, if any, into the third decade counter; and counts while up-count (UPC) and down-count (DNC) pulses, are produced, storing the counts, which are a measure of the value of the impedance under test.

5. A 60-kHz oscillator that serves as a clock for the counter and for furnishing UPC and DNC timing pulses.

6. Logic circuits that produce, under control of the above mentioned circuits, switching signals (UPC, DNC, SUD, STC) for the ratio meter.

7. Circuit that detects the count-complete signal (CP2) from the ratio meter.

8. Quadruple bistable latches and 2 dual 4:1 multiplexers that furnish data stored in the counter to the readout display and to the rear-panel DATA connector and the comparator, if included in the instrument.

9. Scan oscillator and associated flip-flops and IC gates that produce time-state and timing signals for reading out measurement data from the latches and multiplexers to the appropriate light-emitting diode's (LED's) in the readout display. These same signals are furnished to the comparator, for various timing operations, if the comparator is installed in the instrument.

10. Transistor drivers for signals applied to all the readout LED segments and for enabling the LED's.

11. Provision for supplying instrument timing and status signals to peripheral items, including the optional limit comparator, and for accepting external control signals.

The power supply consists of a transformer and rectifier assemblies and a power supply board, P/N 1685-4730. The transformer is mounted at the left-hand rear of the instrument as viewed from the front. The rectifiers are mounted just to the rear of the board, in front of the transformer, on the transformer terminal board. The board is mounted in front of the transformer, under a metal cover Three filter capacitors are located beneath the circuit board. The power supply furnishes +5V and ±15V to all circuit boards in the instrument.

The optional limit comparator is comprised of two circuit boards and a front-panel assembly. These units are installed separately in the unit. The front-panel assembly contains digit-switches for establishing the high and low limits for comparison, and lamps that indicate the status of the comparisons.

The circuit boards are designated A and B (P/N's 1685-4750 and -4760, respectively). The B board contains four dual multiplexers that, under control of logic-board timing signal, switch the status of the digit-switches, first the low-limit switches then the high-limit switches, to the A board where the switch settings are compared with the measured value.

The A board contains a number of timing circuits that sequentially compare each digit of the measured value with the BCD data from each limit comparator switch, beginning with the low-limit switch. When the measured value fails to compare with any limit digit, the appropriate lamp(s) light.

The comparator has provisions for furnishing status signals to peripheral equipment and allowing external connections to be made to the logic board for unique operations.

## 4.2 CIRCUIT DESCRIPTIONS

### 4.2.1 General

The following paragraphs contain descriptions of the 1685 circuits in the signal-flow order shown in Figure 4-2. To obtain a general overall view of how the instrument

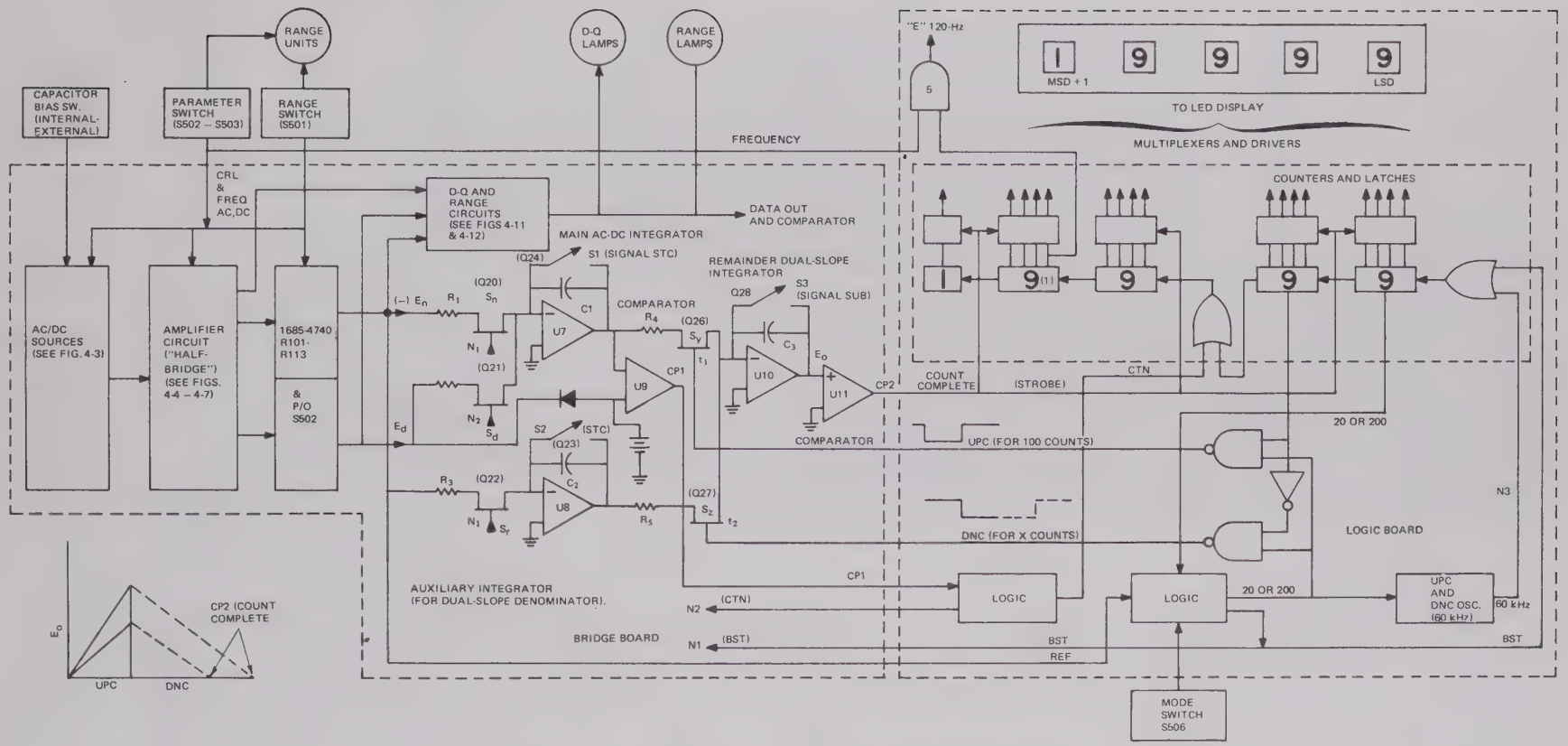



**Figure 4-2. Detailed block diagram of the 1685 Digital Impedance Meter.**

SEQUENCE OF OPERATION

1. S1, S2, AND S3 CLOSED (INITIAL CONDITIONS).
2. PRESS MODE SWITCH (START).
3. DELAY AND CLEAR CIRCUITS (RESET).
4. OPEN S1 AND S2 (BY MEANS OF SIGNAL STC).
5. APPLY N1 BURST (BST) PULSES (20 FOR 120-Hz OPERATION; 200 FOR 1-kHz) TO $S_n$ AND $S_r$.
6. IF CPI HIGH, APPLY N2 PULSE(S) CTN TO $S_d$ AND COUNT PULSES. (USE 'HUNDREDS' DECADE COUNTER.)
7. COUNT BST PULSES WITH COUNTER. (USE 'UNITS' AND 'TENS' DECADES.)
8. AFTER 20 OR 200 BST PULSES, OPEN S3. ('UNITS' AND 'TENS' DECADES AUTOMATICALLY RESET.)
9. CLOSE $S_y$ FOR TIME IT TAKES COUNTER TO COUNT 100 UP-COUNT (UPC) PULSES. TIME=100/60 kHz. (COUNTERS 'UNITS' AND "TENS" AUTOMATICALLY RESET.)
10. OPEN $S_y$ AND CLOSE $S_z$.
11. COUNTER COUNTS N3 DOWN-COUNT (DNC) PULSES (60-kHz RATE).
12. COUNT N3 PULSES UNTIL $E_o$ CROSSES ZERO LEVEL (PRODUCES COUNT COMPLETE , CP2.)
13. STROBE COUNT OUT OF ALL COUNTERS INTO LATCHES AND THROUGH MULTIPLEXERS TO LED DISPLAY. THIS IS MEASUREMENT VALUE.

ALSO REFER TO TIMING DIAGRAM, FIGURE 6-9.

operates and how it functions in comparison to other bridges, refer to the appendix at the rear of this section. In the appendix, disregard the specifications that are called out. They are included only to give a better understanding of some operations.

### 4.2.2 Component Identification and Definitions.

*Component Identification.* In the following paragraphs, references are made to components shown in the schematics. Since many of the logic integrated circuits referenced on the schematics have several components in a single package that has a single reference designator, it is necessary to use a scheme that identifies, where necessary, the particular circuit in the package. Packages are identified on the schematics either by numbers or by numbers preceeded with the letter U.

To identify most circuits in a package, the output pin or terminal is used in the text, in addition to the letter designation. (For example, a NAND gate can be referenced IC5-9 or U5-9, where 5 is the package reference designator and 9 is the output terminal of a particular gate in the package.)

In the case of flip-flops (F-F's), the Q terminal is referenced to identify the particular F-F in the package. (For example, U8-6, where U8 is the package designator and 6 is the Q terminal of the particular F-F.) Reference designators for other components such as transistors, resistors, etc., are standard.

*Logic Definitions.* In the text, a "high" level (or a logic 1) is defined as positive TTL-compatible logic, +3.5V to +5V. Where open-collector circuits are used, the high, or logic 1, can be a maximum of 30 V (or $+2V < V_H < +30$ V).

A "low" (or logic 0) is approximately 0 V. Where open-collector circuits are used, the low is $0V < V_L < 0.4V$, where the "open" is equivalent to $V_L$.

### 4.2.3 Bridge Board (Figure 6-4).

*General.* Figure 4-2 is a fairly detailed block diagram of the instrument. This description follows the signal path shown in the Figure.

*Oscillator and Dc Source.* Figure 4-3 shows the equivalent circuit of the Wien-bridge oscillator. The oscillator can be considered to be two parts, a frequency-determining network ($C_A$, $C_B$ and $R_A$), that supplies positive feedback to sustain oscillation, and a voltage divider ($R_F$ and $R_E$) that furnishes negative feedback to stabilize the amplitude. The oscillator has two frequencies, 120 Hz (or 100 Hz) and 1 kHz, selected by means of front-panel PARAMETER switch S502, which changes the values of $R_A$ and $C_A$ by switching in either Q5 or Q6, respectively. Figure 6-4 shows the connections. $R_F$ is a thermistor that adjusts itself to the value needed to maintain a constant amplitude. The circuit oscillates at frequency $F = 1/2\pi RC$. R25 is a 1-kHz frequence adjustment. The oscillator can furnish low frequencies of either 120 or 100 Hz. The latter is obtained by removing the shorting

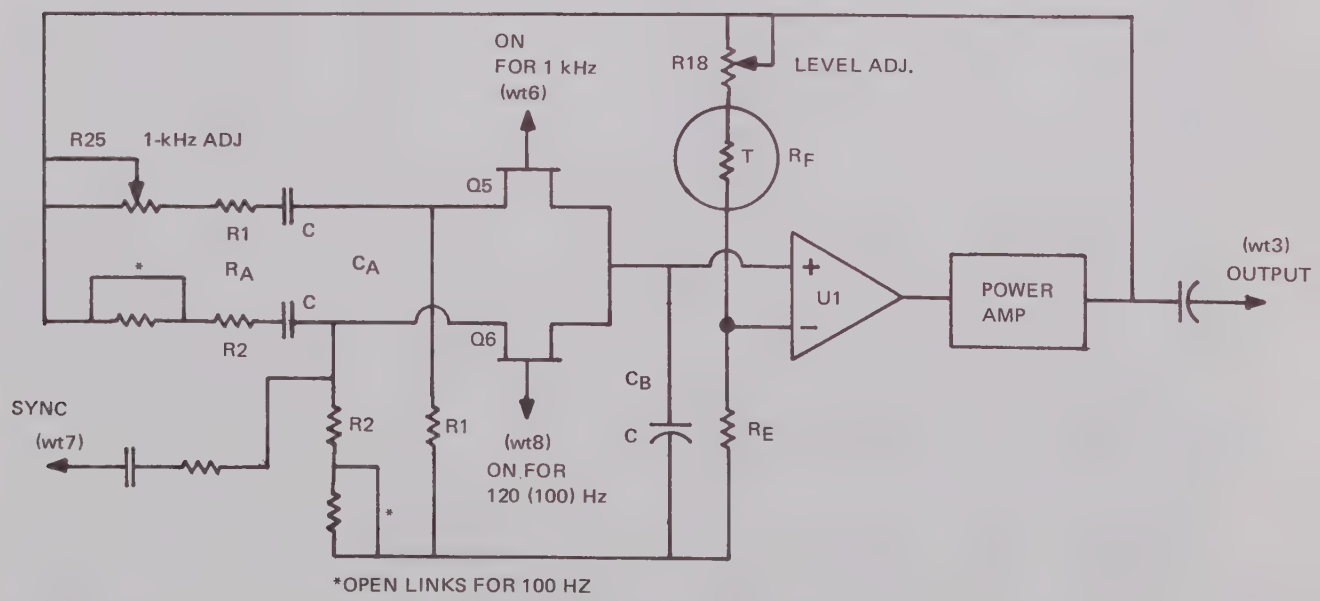



**Figure 4-3. Oscillator equivalent circuit.**

wires across R144 and R279 to increase the resistance values. If the desired oscillator signal is twice one line frequency (50 or 60 Hz), the synchronization signal to WT7 should be solder-connected. If the oscillator signal is not twice the line frequency the synchronization line should be disconnected, in which case the frequency will be accurate to ±2%.

The input to the power amplifier comprised of Q1-Q4 is a 5-V, rms, 120-Hz or 1-kHz signal from the bridge oscillator. The amplifier can supply 0.1 A rms of current with low distortion. The circuit is short-circuit proof.

The 5-V oscillator amplifier output is applied to 9-position RANGE switch S501 which divides the open-circuit signal level, to give 5 V on ranges 8 and 9, 1 V on ranges 3-7, and 0.1 V on ranges 1 and 2. Series resistors are also added (R1-R6) to limit the short-circuit current.

*Dc Bias Circuit.* As shown in the circuit schematic, Figure 6-4, the internal DC bias is derived from the instrument's DC power supply that furnishes +15 V to a voltage divider network on CAPACITOR BIAS switch S503. The voltage divider is comprised of R10, R11, and R269. There are 4 switch positions shown on the schematic. Switch position 3 supplies 2 V to the part under test. Switch position 4 allows an external bias of up to 100 V to be applied to the part under test. (Care must be taken to include a resistor in the connection if the external supply is a high-current supply.)

Switch position 1 removes the bias; switch position 2 is undetented and is used to discharge C502 when the switch is between positions 2 and 3.

*Amplifier Circuit.* The meter cirucuit contains amplifiers that furnish voltage outputs proportional to the voltage across and the current through the unknown, two phase-shift networks for the ac measurements for bringing the signals in phase* for purely reactive unknowns, and an AC-DC ratio meter that indicates the ratio of the vector components of two voltages obtained from the amplifiers, to obtain the desired measurement value.

The voltage and current-sensing amplifiers are illustrated in Figure 4-4. The circuit is described as a "half-bridge" because of the similarity in function to the unknown and ratio arms of a passive four-arm impedance bridge. The section that furnishes the output proportional to the voltage across the unknown can be considered the $Z_X$ arm; the section that furnishes a voltage that is proportional to the current through the unknown can be considered the $R_S$ arm.

In addition to furnishing the voltage proportional to the current through the unknown the Rs arm also furnishes a reference for the ratio meter for inductance and capacitance measurements. (Reference signals are via the logic board.)

Figures 4-5 to 4-7 show the "half bridge" configurations for capacitance, inductance and resistance measurements. For capacitance and inductance measurements the signals are phase shifted so that the signals are inphase* when a pure inductance is being measured. Bandpass networks are used which are similar except for the RC connections, which result in 90° phase differences between them. The networks are interchanged for these measurements by means of front-panel PARAMETER switch S502. The networks are not

*—$E_n$ and $E_d$ are actually exactly 180° out of phase.

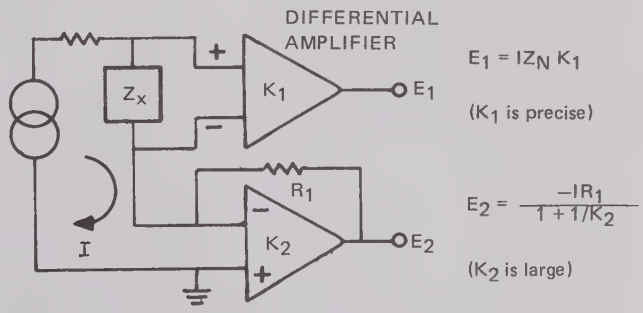



**Figure 4-4. Basic "half-bridge" containing two arms, Zx and Rs.**

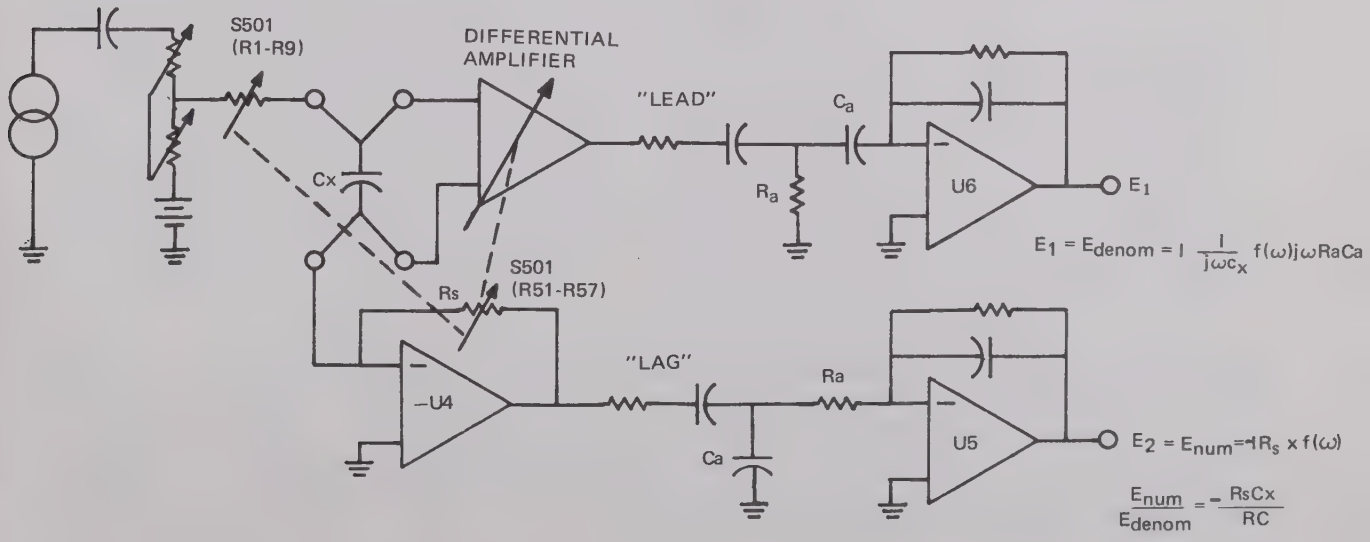



**Figure 4-5. Series capacitance ($C_s$) bridge configuration.**

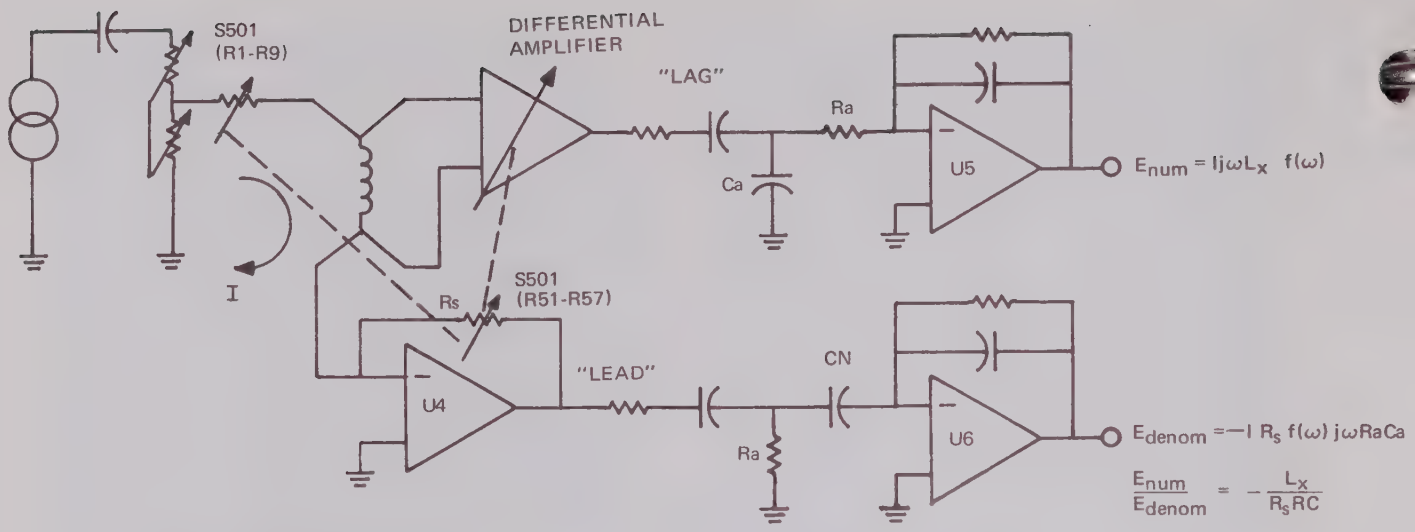



**Figure 4-6. Series inductance bridge configuration.**

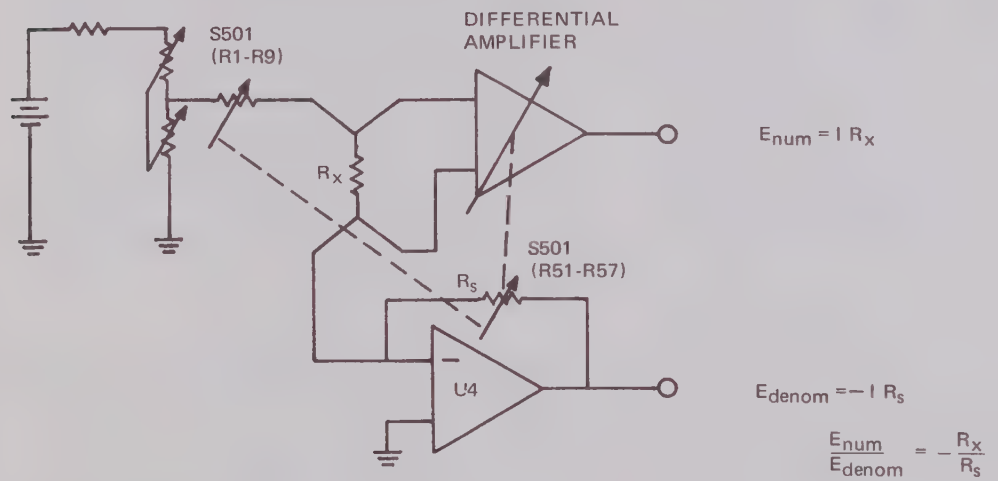
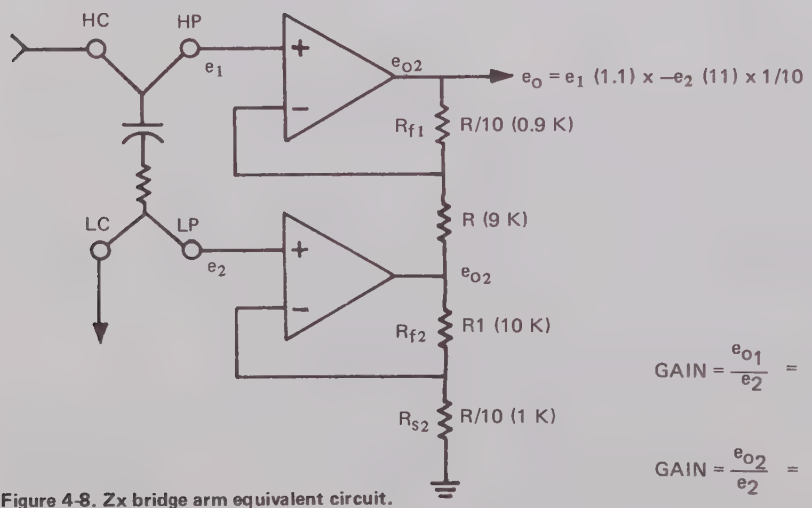


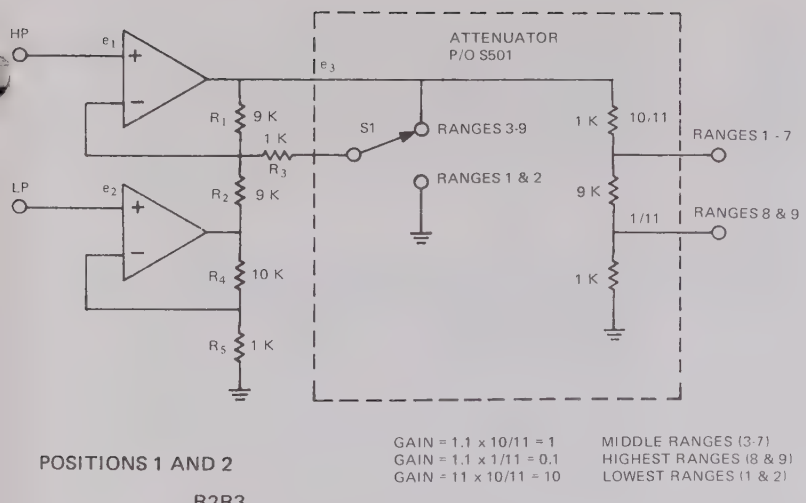

**Figure 4-7. Resistance ($R_{dc}$) bridge configuration.**




$$GAIN = \frac{e_{o1}}{e_2} = \frac{R_{f_1} + R_{s_1}}{R_{s_1}} = \frac{R_{f_1} + 1}{R_{s_1}} = \frac{9 + 0.9}{9} = 1.1$$

$$GAIN = \frac{e_{o2}}{e_2} = \frac{R_{f_2} + R_s}{R_{s_2}} = \frac{R_{f_2} + 1}{R_{s_2}} = \frac{10 + 1}{10} = \frac{11}{10} = 1.1$$

**Figure 4-8. Zx bridge arm equivalent circuit.**




GAIN = 1.1 x 10/11 = 1 MIDDLE RANGES (3-7)
GAIN = 1.1 x 1/11 = 0.1 HIGHEST RANGES (8 & 9)
GAIN = 11 x 10/11 = 10 LOWEST RANGES (1 & 2)

POSITIONS 1 AND 2

$$e_3 = e_1 \frac{R1 + \frac{R2R3}{R2+R3}}{\frac{R2\,R3}{R2+R3}} - e_2 \frac{R4 + R5}{R5} \times \frac{R1}{R2}$$

$$e_3 = e_1 \frac{9.9}{0.9} - e_2 \frac{11}{1} \times \frac{9}{9}$$

$$e_3 = (e_1 - e_2)\,11$$

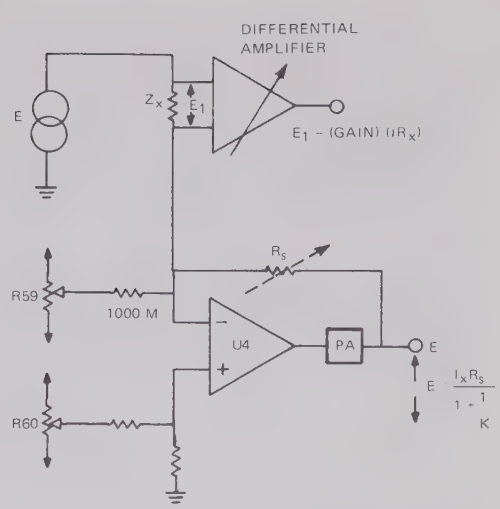
POSITIONS 3-9

$$e_3 = e_1 \frac{\frac{R1\,R3}{R1+R3} + R2}{R2} - e_2 \frac{R4 + R5}{R5} \times \frac{R1\,R3}{R1+R3}{R2}$$

$$e_3 = e_1 \frac{9.9}{9} - e_2 \frac{11}{1} \times \frac{0.9}{9}$$

$$e_3 = (e_1 - e_2)\,1.1$$

**Figure 4-9. Zx bridge arm and output attenuator equivalent circuit.**




$E_1$ = VOLTAGE TO DIFFERENTIAL AMP
$E_1 = I_X Z_X$
$Z_X$ = UNKNOWN
$Z_A$ = SHUNT RESISTANCE
$R_S$ = RATIO ARM (SELECTED BY RANGE SWITCH)

**Figure 4-10. $R_S$ arm equivalent circuit.**

used for resistance measurements. Figures 4-8 and 4-9 are more detailed equivalent diagrams of the $Z_X$ arm of the "half-bridge." A differential amplifier comprised of operational amplifiers U2 and U3 is employed to detect the voltage drop across the unknown. The gain of both amplifiers is determined by the resistors in their feedback network, as shown in Figure 4-8. Each input is amplified by the same factor (as determined by the resistors), so that the output is proportional to the difference between the input voltages.

The attenuator, comprised of components mounted on RANGE switch S501, determine the amplifier's overall gain, as shown in Figure 4-9, which identifies the components and illustrates how the gain is obtained for the various ranges. There is a gain of 1 for the middle ranges (3-7), a gain of 0.1 for the highest ranges, and a gain of 10 for the two lowest ranges (1 and 2).

The $R_S$ arm is comprised of operational amplifier U4 and a power amplifier comprised of transistors Q7-Q10. The arm resistance is selected by means of RANGE switch S501, which switches in various values for $R_S$ in the amplifier feedback loop. Table 4-1 lists the resistors (R51-R57) in the ratio arm for the 9 instrument ranges.

**Table 4-1**
**$R_S$ VALUES AND DIFFERENTIAL AMP GAIN**

| Range | Resistor (Ω) | Differential Amp Gain |
|---|---|---|
| 1 | 1 | 10 |
| 2 | 10 | 10 |
| 3 | 10 | 1 |
| 4 | 100 | 1 |
| 5 | 1k | 1 |
| 6 | 10k | 1 |
| 7 | 100k | 1 |
| 8 | 100k | 0.1 |
| 9 | 1M | 0.1 |

Op amp U4 in the arm is an inverting amplifier. It has adjustments at the positive and negative inputs to cancel out the offset voltage and current between the inputs, which offset the accuracy of the dc resistance measurement. R60 is the voltage adjustment most critical on the low resistance ranges. R59 is the current adjustment most critical on the highest resistance ranges.

Figure 4-4 shows the equivalent circuit of the amplifier. U4 is followed by a push-pull, unity-gain power amplifier (Q7-Q10) required to obtain the higher currents used on the lower impedance ranges. The ratio-arm resistor, $R_S$, and the differential amplifier gain determine the impedance range. (See Figures 4-4 and 4-10.)

Depending on the type of component being measured, the outputs of the inverter and differential amplifiers are switched by means of the PARAMETER switch between either the bandpass network comprised of U6 or the one comprised of U5. (See Figures 4-5 to 4-7.) For resistance measurements, the arm is connected directly to the ratio meter.

The two bandpass networks are identical, except the capacitors and resistor are interchanged. The networks act to phase-shift the signals so that they are inphase when a pure reactance is being measured. Figures 4-5 to 4-7 show the equivalent circuit. The ratio of the transfer functions of these two circuits is $j\omega R_a C_a$, giving the required 90° phase shift. (Since only the ratio $E_1/E_2$ is desired, the transfer functions of each separately is not critical.)

If the unknown capacitor in Figure 4-5 has loss, and the effective series value of capacitance $C_{xs}$ is desired, then the unknown in Figure 4-5 should be represented as a series resistance, $R_x$, and a series capacitance, $C_{xs}$.

Then, $$E_1 \sim I \left[ R_x + \frac{1}{j\omega C_{xs}} \right] j\omega R_a C_a f(\omega),$$

$$E_2 \sim I R_s f(\omega).$$

If $E_{apb}$ is defined as the component of $E_a$ inphase with $E_b$, then

(1) $$E_{apb} = \text{Real} \left[ \frac{E_a}{E_b} \right] \left| E_b \right|.$$

It is easy to see that

(2) $$\frac{E_2 p_2}{E_1 p_2} \sim \frac{R_s C_{xs}}{R_a C_a}$$

Note that the $f(\omega)$ terms cancel out. Thus, the series value of $C_x$ is measured.

For the inductance measurement configuration of Figure 4-6, the inductance has loss it can be represented by a series resistance, $R_x$, and a series inductance, $L_{xs}$.

For Inductance Measurements, if the series inductance $L_{xs}$ is desired, then

$$E_1 = E_{num} = (R_x + j\omega L_{xs}) f(\omega) I,$$

$$E_2 = E_{denom} = I R_s j\omega R_a C_a f(\omega),$$

and

$$\frac{E_1 p_2}{E_2 p_2} = \frac{L_{xs}}{R_s R_a C_a}.$$

So that inductance is measured.

*Ratio Meter.* The principle of the ratio-meter operation is described below and also in the appendix to this section of the manual. The meter makes a ratio measurement in two steps. First, the main integrator (U7) determines the first digits of the result by a pulse-counting technique; then the auxillary integrator (U8) and the dual-slope integrator (U10) determine the remaining lesser digits.

The main integrator is a combination of a phase-sensitive detector and integrator. To start its operation, its capacitor (C40 for 1-kHz and C40 and C41 for 120-Hz operation) is unshorted, and a train of pulses N1 (200 for 1-kHz, 20 for 120 Hz) is applied to the switch (Q20) that connects the numerator voltage to the input. These pulses are square waves inphase with the reference signal. Each pulse will cause an increase in the integrator output that is proportional to the size of the vector components of the numerator voltage, which is inphase with the reference. (See Appendix, Figure 4.)

The output of the integrator is connected to a comparator (U9) that is offset by a threshold voltage derived from the denominator signal. Whenever this threshold level is exceeded, the next pulse in the train is also applied to the denominator switch (Q21). At the end of the burst, a total of N2 denominator pulses will have been applied; the number of pulses depends on the relative size of the numerator.

At the end of the burst, the output of the integrator, which is termed the remainder voltage, is

$$E_{rem} = \frac{N1\, E_{npr}}{\pi R1\, C1\, f_1} - \frac{N2\, E_{dpr}}{\pi R2\, C1\, E_1 f_1}, \quad (1)$$

where Enpr and Edpr are the vector components of the numerator and denominator signals inphase with the reference signal, and $f_1$ is the frequency

Note the same capacitance appears for dc resistance measurements

$$E_{rem} = \frac{N1En}{2f\, R1C} - \frac{N2E_d}{2f\, R2\, C}, \quad (2)$$

where f is 1 kHz.

Thus,

$$\frac{E_{npr}}{E_{dpr}} = \frac{N2}{N1} \cdot \frac{R1}{R2} + \frac{\pi R1C1f_1}{N1} \cdot \frac{E_{rem}}{E_{dpr}}. \quad (3)$$

The first term in this expression for the ratio is used to determine the first digits of the measurement. The count N2 is injected into the third digit of the display counter, thus giving a reading of N2x100.

To determine the remainder count, the ratio $E_{rem}/E_{dpr}$ is taken into account. The value of $E_{dpr}$ is determined by the auxillary integrator, U8, to which the burst of N1 pulses is applied. At the end of the burst, the integrator output

$$E_{aux} = \frac{E_{dpr} N1}{\pi R3\, C2\, f_1}, \quad (4)$$

or

$$E_{dpr} = \pi R3C2f_1 E_{aux}. \quad (5)$$

Substituting this in (3)

$$\frac{E_{npr}}{E_{dpr}} = \frac{N2}{N1} \cdot \frac{R1}{R2} + \frac{R1C1}{R3\, C2} \cdot \frac{E_{rem}}{E_{aux}}. \quad (6)$$

$E_{rem}/E_{aux}$ is measured in a dual-slope integrator (U10). $E_{rem}$ is applied to this integrator through R4 for time $t_1$, which is the time for 100 cycles of the 60 kHz ($f_2$) oscillator. This $t_1 = 100/f_2$, and this produces an output voltage

$$\frac{E_{rem}\ 100}{f_2\ R4\ C3}.$$

$E_{aux}$ (of opposite sign) is then applied until the output of the integrator is returned to zero, as determined by a comparator (U11). The time it takes to return the output to zero, $t_2$, is determined by counting the cycles of $f_2$ during this period. This $t_2 = N3/f_2$.

Since the positive (up) voltage due to $E_{rem}$ equals the negative (down) voltage due to $E_{aux}$

$$\frac{E_{aux}\ N3}{C3\ R5\ f} = \frac{E_{rem}\ (100)}{R4\ f\ C3},$$

or

$$\frac{E_{rem}}{E_{aux}} = \frac{N3}{100} \cdot \frac{R4}{R5}.$$

Substituting this in (6)

$$\frac{E_{npr}}{E_{dpr}} = \frac{N2}{N1} \cdot \frac{R1}{R2} + \frac{C1\ R1\ R4}{R3\ C2\ R5} \cdot \frac{N3}{100}. \quad (7)$$

The count, N3, is displayed as the last two bits of the display (which can spill into the more significant bits, if necessary).

At 1 kHz, N1 = 200, C1 R1 R4/R3 C2 R5 = 1/100 and R1/R2 = ½

so that

$$\frac{E_{npr}}{E_{dpr}} = \frac{100\ N2 + N3}{10000}, \quad (8)$$

and a full-scale reading is 19999.

And at 120 Hz, N1 = 20, C1 R1 R4/R3 C2 R5 = 1/10,

so that

$$\frac{E_{npr}}{E_{dpr}} = \frac{100\ N2 + N3}{1000}, \quad (9)$$

and a full-scale reading is 1999.

An important advantage of this circuit is that the critical main integrator uses the same capacitor (C1) for integrating both the numerator and denominator signals; therefore, it need not be highly precise. The components (including that of C2) are important in determining the remainder count, N3, as shown in equation 7, but the N3 count is only a small percent of the total reading.

*D-Q Circuit.* Figure 4-11 shows the equivalent D-Q circuit. The circuit is comprised of a NAND gate and FET switch; an inverting amplifier (U17); RC filters; the front-panel D-Q potentiometer, R501, and associated filter network; a comparator; and a bistable flip-flop comprised of Q34-Q37 that controls the state of the front-panel D-Q lamps.

The dissipation-factor is obtained by using the phase angle difference, $\phi$, between the numerator and denominator signals, as shown in Figure 6-4. Both of these signals are converted into pulses which are applied to the NAND gate. This gives an output pulse whose length is proportional to the phase angle difference. If the phase angle, and not dissipation factor were desired, the RC network shown in Figure 4-11 would just comprise a resistor, which would pass a fixed current for the length of the phase-difference pulse. U17 and the RC network at its output would then filter the signal to give a DC current proportional to the phase angle (Ø) difference. Normally, this dc current would be balanced by the DC current furnished from the D-Q potentiometer to produce a high or low 'D' indication.

Since the measured value is dissipation factor, however, which is tan Ø, and not Ø in characteristic, and since it is desirable to have the D-Q meter scale nonlinear (approximately logarithmic over the middle part of the scale), an RC network is used at the input to U17 instead of a single resistor so that the current flowing through the network is not constant, but time dependent. This gives greater sensitivity to low D reading, and compresses the scale at high D readings.

Two input RC networks are used, one for each test frequency. Each differs in the capacitor used, and the appropriate network is selected for the test frequency being used. The proper RC current-source network and FET gate is selected by means of front-panel PARAMETER switch S502. When set to a 120-Hz position, for example, the switch furnishes a negative voltage to wire-tie (WT) 27 and a positive voltage to WT25. The negative voltage, which passes through diode CR33, holds FET Q27 off and, therefore, the 1-kHz section of the D-Q circuit, turned off. A negative voltage is also furnished by transistor Q30, via diodes CR30 and CR31, to both Q31 and Q32. If Q30 is turned on, the cathodes of CR30 and 31 will go to ground, and the FET that has the positive voltage applied to it via the PARAMETER switch will be turned on, since the FET gate input will also go to ground. (The negative voltage already at the gate of Q31 will remain negative, since the negative voltage is also applied to the anode of CR30 and cannot go to ground through the diode.)

*Note that jumpers must be added* to the 120-Hz current-source network if the instrument is to be operated in the 100-Hz test frequency mode. (Refer to Section 2 of the manual.)*

*The instrument is purchase connected for a 50- or 60-Hz line frequency and, therefore, 100- or 120-Hz test frequency, respectively.

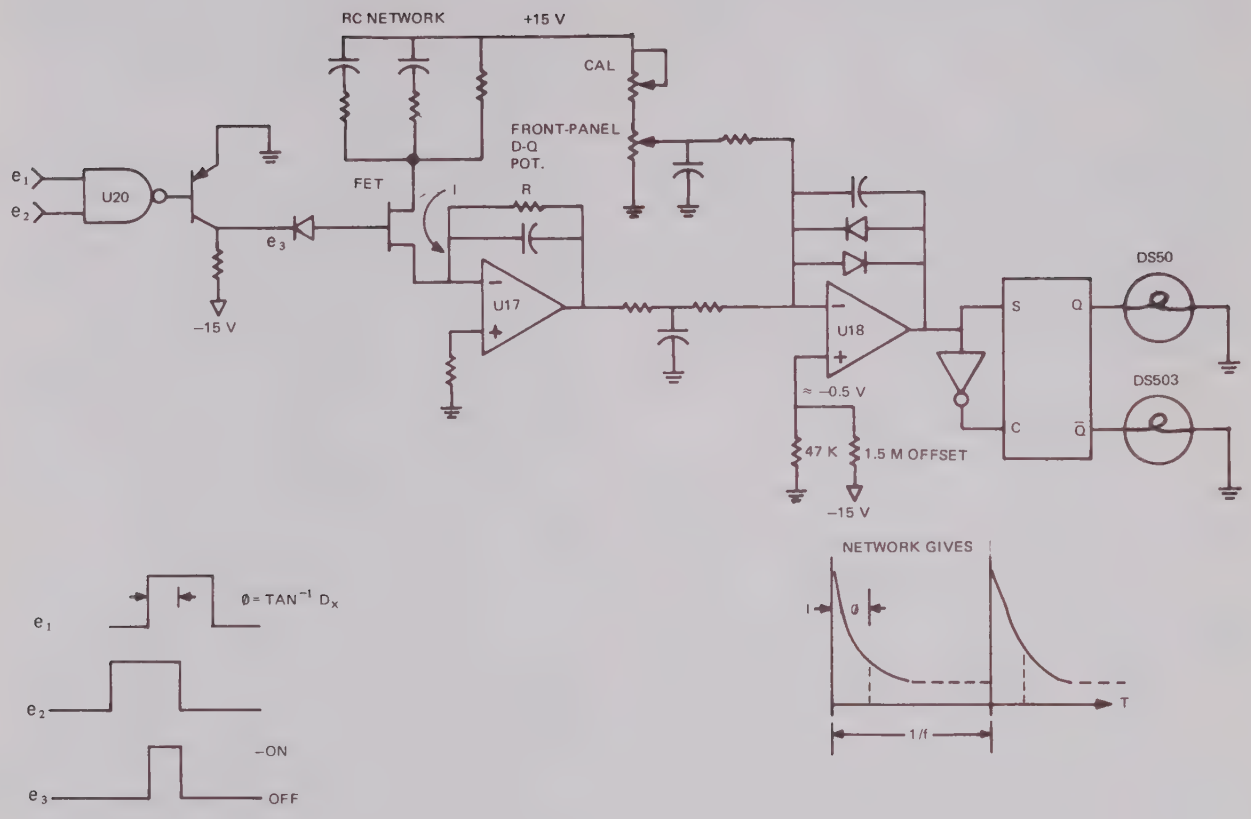



**Figure 4-11. Simplified D-Q circuit.**

To ensure that the circuit operates when the D factor is zero, the offsets (the Ø adjustments) on the potentiometer board (P/N 1685-4740) are adjusted slightly so that there is a minimum pulse at the FET gates. This allows the D-Q switch to be adjusted through zero to a negative value to obtain a balance around zero for a capacitor with a D factor of zero. To do this, a certain amount of pulse is required through the NAND and FET gate so that the circuit can operate; the slight adjustment in lead or lag of the Ø potentiometers will allow this to occur. The full-scale reading is set by R236, which varies the voltage on the D-Q potentiometer.

When the output of U18 is positive, which means that the input is negative and, therefore, the measured D exceeds the value set on the dial, Q34 is turned on and Q37 is turned off. Q34 turns on Q35, which causes approximately +5 V to be applied, via WT24, to lamp DS504, turning on the lamp. This indicates the dial should be set to a larger value if it is desired to obtain the exact reading. If the output of U18 is negative, indicating a positive input to U18 and, therefore, a setting on the dial larger than the measured value, Q34 is turned off and Q37 is turned on. This, in turn, turns on Q36 and lamp DS503 on the front panel. This indicates that the dial should be set to a lower value if it is desired to obtain the exact reading.

If the exact setting is set on the dial, a slight amount of ac on the input U18 causes both D-Q lamps to be illuminated.

The circuit operates in the same manner for a storage factor, Q, measurement. Storage factor is the reciprical of D, and either Q or D may be used, as desired.

*Range Circuits.* The range circuits detect signal levels that indicate that the range selected by means of the front-panel RANGE switch may either be too high or too low, or is within the proper range. If the selected range may be high or too low, the circuits furnish signals that light direc-

tion lamps on the front panel, to indicate the direction that the dial should be turned to obtain the correct range. To do this, a high-range detector and a low-range detector circuit is employed to sense by means of comparing at a junction the dc level of each "half-bridge" signal ($e_n$ and $e_d$). If signal $e_n$ is greater than twice signal $e_d$, the high-range lamp will light, indicating that the measurement is too high for the range and the range should be increased. If signal $e_n$ is less than 1/5th $e_d$, the low-range lamp will light, indicating the range should be decreased.

Figure 4-12 shows the equivalent range circuits. The numerator and denominator signal are each applied to isolation amplifiers and summed in a weighted resistor network. The summing point is shunted to ground by an FET gate (Q44) driven by the reference signal. This results in phase detection of the signals.

The two signals are of opposite polarity; therefore, if $E_n/R1 > E_d/R2$, the output, $e_3$, will be positive, and the HIL lamp will light. The value of $E_n/E_d$ at which this occurs depends on the ratio R1/R2, and is set just below a full-scale reading. If the HIL lamp is lit, it indicates a higher range should be used.

The LOL lamp is actuated in the same manner if $E_n/R3 < E_d/R4$. R3 and R4 are chosen to light the lamp if the reading is just below 1/10th full scale, where a lower range should be used for better resolution.

The range lamps function continuously and do not require a start pulse. They are, however, only approximate. The actual digital reading may indicate that the range that is set is not exceeded (no E readout), even though the HIL lamp is illuminated, or that a lower range is preferable (one reading less than 1/10th full scale), even though the LOL lamp is not illuminated.

When a range (usually 1 and 9) selected by means of the dial is not applicable and usable for a particular component value, a lamp illuminates through a dial aperature shaped as an arrow. The arrow indicates the direction in which to turn the dial to obtain the next applicable range.

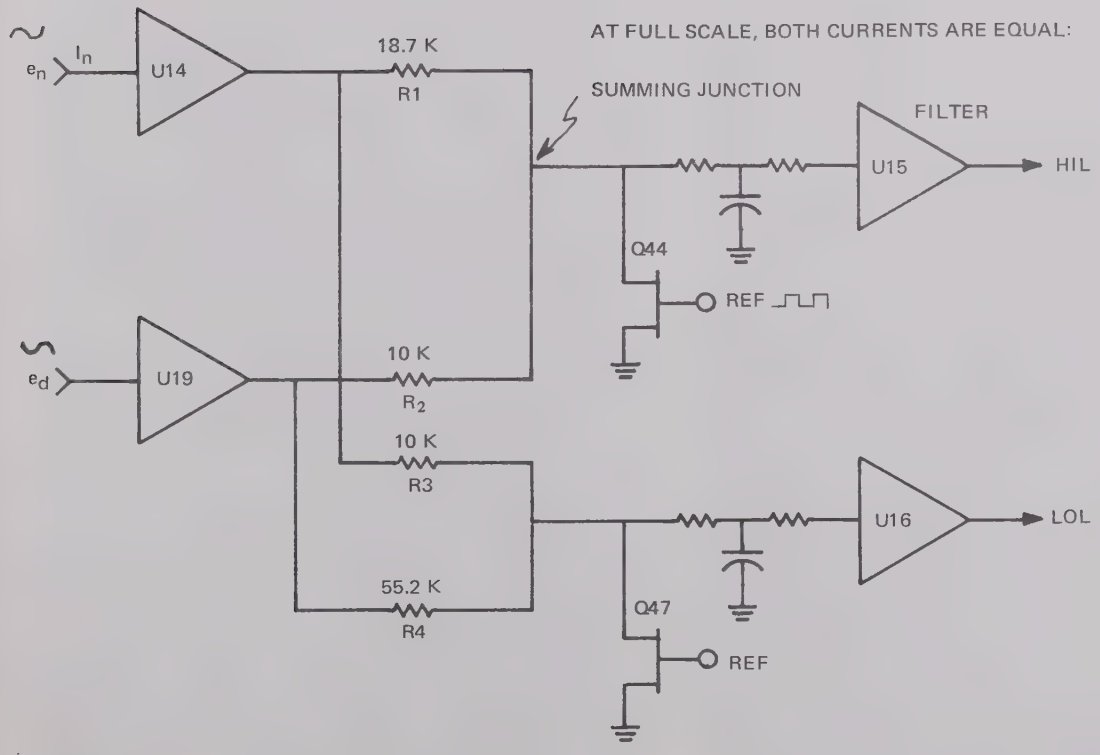



**Figure 4-12. Equivalent range circuit.**

*RANGE and PARAMETER Switches.* Figure 6-8 is the schematic of the front-panel RANGE and PARAMETER switches, S501 and S502 respectively. Figures 6-7 and 6-6 are the respective layout drawings of the switches.

S501 is a 9-position rotary switch having six wafers on which are mounted capacitors and resistors. The layout drawings identify and show the locations of the components. The schematic of the ratio meter and "half-bridge" circuits (Figure 6-4) shows the components and illustrates their functions in the circuits. Besides their main function of establishing the analog measurement, the RANGE and PARAMETER switches are also used for other purposes. As shown in switch schematic, Figure 6-8, the high and low range-direction lamps are activated (or disabled) via S502 and S501. Note that for certain switch positions no range lamp(s) will light. In Figure 6-8, the RANGE switch is shown set to range 1; the PARAMETER switch is shown set to C 1 kHz. The PARAMETER switch then rotates through C 120 Hz, RDC, L 120 Hz, and L 1 kHz.

The range direction lamps are always lit on range 1, except for C 120 Hz. They are also always lit on range 9, except for RDC. (Range 1 is not recommended except in certain cases and range 9 is not usable except for DC measurements. (Refer to para 3.3 for details.) Also, the range lamp indication that normally occurs to indicate that the measurement is less than 1/10th full scale will not occur on ranges 1 and 2 for RDC, L 120 Hz and L 1 kHz (signal LOL is disabled at S501) and on range 8 for C 120 Hz and C 1 kHz (signal LOL is disabled at S501), so that a non-recommended or unusuable range will not be selected by the operator.

The +5 V is used to illuminate the range direction lamps on range 1 for all parameters except C 120 Hz; and for all parameters on range 9 except for RDC; it is applied to contact 201F of S502. By tracing this signal through the various switch contacts, it will be seen the range direction lamps are held illuminated for the ranges mentioned above. For other ranges, the lamps are illuminated by signals LOL and HIL when the measurements are less than 0.1 full scale or within 5% full scale, respectively.

The same +5 V used to hold the lamps illuminated in ranges 1 and 9 is also used to activate the D-Q circuit by furnishing, via contact 218F of S502, the +5 V to WT23 on the bridge board.

When S502 is set for C measurements, an effective high signal is applied to WT9 on the bridge board by means of the same +5-V source. This selects the reference signal for the range circuits from the "lag" (numerator) section of the "half-bridge." When L and R measurements are being made, a ground is applied to WT9, causing the reference signal to be taken from the "lead" (denominator) section of the bridge.

The decimal point selection for the readout display is made by means of S501 and S502, as shown in Figure 6-8. A +5-V dc signal is furnished over either line A, B or C to the logic board via connectors J502 and S02. Table 3-1 in Section 3 gives the decimal-point placement for each of the nine ranges for each parameter selected. Lines A, B and C are for decimal points DP4, DP3 and DP2, respectively, as shown in Figure 6-11, the schematic diagram of the display board. Lines A, B and C are also available at the rear-panel MEASUREMENT DATA connector, for use by external equipment.

S502 also selects the units symbol lamps for use with the RANGE switch. The switch also is used for the test-frequency selection, for D-Q circuit frequency selection, and for selection of an additional capacitor in the main integrator circuit, for the 1-kHz mode of operation.

When S502 is set to the 120-Hz position, a positive voltage is applied to WT's 8, 26, and 13 to enable the 120-Hz (or 100-Hz) oscillator, enable the 120-Hz (or 100-Hz) section of the D-Q circuit, and select the additional sampling capacitor in the integrator, respectively. These connections are also shown on the bridge board schematic.

When set to a 1-kHz or R position, the switch furnishes a positive voltage to WT's 6 and 27 to enable the 1-kHz oscillator and 1-kHz section of the D-Q circuit. The alternate switch furnishes a negative voltage to the WT's not connected to the positive voltage.

Figure 6-5 shows the layout of the CAPACITANCE PARAMETER switch, S503. The switch schematic is contained in the bridge board schematic, Figure 6-4.

**4.2.4 Logic Board.**

*General.* The following is a description of the sequence of measurement operations, and includes primarily the operation of the logic circuit board, which furnishes the timing and control signals for the measurements. Figure 4-2 is a block diagram of the ratio meter and a portion of the logic board circuitry. Included in the figure is a brief sequence of operations of the unit. The following paragraphs expand on this brief description, to explain the reasons why and how the control signals produce this operational sequence for all measurements.

Refer to Figure 6-10 for the logic board schematic. It is suggested that the reader also refer to the timing diagram of Figure 6-9, when reading the following description.

*Reset, Burst and Time Signals.* The logic circuit operation up through the period designated BURST at the top of Figure 6-9 is described in this paragraph. When power is initially applied to the instrument, transistor Q27 turns on momentarily. This triggers U38, which produces a RESET pulse at U38-1 and U38-6 to initialize (reset) all logic storage elements.

When the START switch is pressed, one-shot IC38 is triggered by signal START at pin 4. The one-shot produces a 15-ms pulse at pins 6 and 1 that is used to reset decade counters U2, U3, U8, U13 and U26. These counters are used to count burst pulses (20 or 200), comparator pulses (CP1) that correct the integrator threshold, up-count (UPC) and down-count (DNC)-time pulses, and display, via their

outputs which are applied to other devices, the value of the part under test. The CP1 count X100 and DNC-time counts comprise the value of the part under test.

IC38 can also be triggered by an external REMOTE START signal applied to its input pin No. 3 via either the rear-panel MEASUREMENT-DATA connector or the Limit Option module, allowing external devices to initiate measurements. Figure 6-10 shows the MODE switch set to SINGLE MEASUREMENT. If repetitive measurements are being made (MODE switch set to REPETITIVE), timer U39 will be triggered at pin 2, since its input at pin 4 is switched to a logic 1 (high) to enable U39 in this mode. The triggering will occur after data is made available for display and/or recording. U39 is automatically re-triggered by pulse $\overline{SD3}$ after counters U2, U3, U8, U13 and U26 have achieved a new value and have stopped counting. U39 causes the output of NAND gate U16-8 to go low for a period determined by timing resistors R500 and 501 on the MODE switch. The low (signal TIME) at the output of gate U16 is applied to pin 5 of IC38, inhibiting U38. When signal TIME goes high after the controlled time (approximately 0.25 s min, 10 s max.), the combination of the low at pin 4 of U28 and the positive-going edge at pin 5 automatically triggers one-shot U28 to produce a RESET pulse at its pin 6 output (and a $\overline{RESET}$ pulse at its pin 1 output), and a new measurement cycle is therefore automatically initiated.

The $\overline{RESET}$ pulse from IC38, pin 1, holds STC low, but allows STC to go high when it ($\overline{RESET}$) goes high. (The input to U37-12, designated CC on the timing diagram, stays high during the time period.) When STC goes high, it opens switches S1 and S2 shown in Figure 4-2 (Q23 and Q24, respectively, in Figure 6-4). These FET switches then remain open until the measurement is completed.

The $\overline{RESET}$ pulse from IC38 also sets cross-coupled flip-flop U29-6, which, at the end of the pulse, causes pin 9 of of J-K flip-flop U28 to go high and pin 12 to go low, allowing the next falling edge of signal REF to change the state of U38. (Signal REF is the reference signal produced by the oscillator on the 1685-4720 bridge board.)

The high now at pin 11 of U28 enables NAND gate U29-11, allowing the next and subsequent REF pulses to pass through the gate as signal BST. The signal is then designated signal BST.

Signal BST, or "burst," is fed back to the bridge board, via S02-C, where it is used as the pulse train for gating of the main AC-DC integrator circuit, as described in paragraph 4.2.3.

The burst is 20 counts when making 120-Hz measurements and 200 counts (or pulses), when making 1-kHz measurements. These pulses must be counted, and decade counters U2 and U3 are employed for this purpose, as well as for other counting functions. Signal BST is applied to NAND gate U32-8. Since J-K flip-flop U36 is held reset by the Q output of J-K flip-flop U34-15, there is a high at pin 10 of U32. This allows BST pulses to pass and be counted by decade counter U3.

For 120-Hz measurements, U3 counts 20 pulses. On the 10th and 20th pulses pin 11 goes low (goes high at the 8 count and again at count 18). If measurements are being made at 120 Hz, pin 5 of U37 is low, since the front-panel PARAMETER switch, shown connected to the base of Q20, keeps Q20 turned off, which in turn keeps a high at pin 9 of U37. Since pin 10 (signal S) of U37 is high during this time, there is a low on pin 5 of U37. The output of the decade counter therefore does not pass through either U35-6 or U37-6, but it causes U37-3 to go to 1 and U35-3 to go to 0. This clocks J-K flip-flop U34, causing its Q output to go to 1 at pin 11. On pulse 20, pin 11 of U3 again goes low. This results in pin 6 of U34 going low, causing U34 to change state again, its Q side going low. This in turn causes J-K flip-flop U34-15 to change state, its Q output going high and its $\overline{Q}$ output going low. $\overline{Q}$ going low resets cross-coupled flip-flop U29 and J-K flip-flop U28, which terminates the BST signal. It also causes flip-flops U34 to be disabled, since the J and K inputs are now 0, via signal S from U33-8. However, U34 remains in the same state until reset at the start of a new measurement cycle.

Note that if the instrument was in the 1-kHz mode of operation, pin 5 of U37 would be high, since Q20 would be conducting. U37, under this condition, allows the output of the first decade counter, U3, to be coupled to U2. Since pin 5 of U37 is now high, pin 5 of U35 is also high. The other input of this NAND gate is connected to pin 11 of U2, the output of the second decade of counting.

In the 1-kHz mode, U3 counts to 10, then U2 counts, via U37-6, until a count of 100 is reached, at which time J-K flip-flop U34-11 is set via U35-6 in a manner similar to that of the 120-Hz mode. The counting process continues in U2 and U3 until U2-11 again goes low (200 pulses have now been counted), thereby causing U34-11 to go low. This causes U34-15 to be set. The outputs at U34-15 and U34-14 perform the same functions described in the previous paragraph.

After full counts, the decade counters are back at their original states (reset state), so that there is no need to actually force a reset in the counters. Note that U34 is reset by a low signal STC (see timing diagram) at a time somewhat after BST is completed, but long before the start of a new measurement cycle (leading edge of the RESET signal).

During the time that the BST pulses are being counted, CP1 pulses can be produced on the bridge board, depending on the value of the unknown. These pulses are fed to the logic board, which produces pulses, as shown in the timing diagram of Figure 6-9.

Pulse CP1 enables J-K flip-flop U28 that produces pulses P and $\overline{CTN}$. Pulse CP1 is produced on the bridge board by the comparator (U9) connected to the main AC-DC integrator. When the integrator exceeds the established threshold level, as described in para. 4.2.3, pulse CP1 is produced by the comparator. CP1 ultimately produces a pulse ($\overline{CTN}$) that is time-synchronized to the next BST pulse

and is fed back to the main integrator to turn on an FET gate (Q21) that samples the denominator signal ($E_d$) from the bridge circuit, to perform an arithmetic decision function by a fixed amount. The $\overline{CTN}$ pulse(s) is also counted by counter U8, via U31-3, which represents the third most significant digit of the readout display. Each $\overline{CTN}$ pulse, therefore, has a value of 100 counts in the counter chain of U3, U2, U8, U13, and U26.

CPI going high asynchronously enables the J and K inputs of U28. U35-11, driven by U28-15 and U33-12, then produces the desired CTN pulse in time synchronization with a BST pulse, as mentioned above and as shown in Figure 6-9. CPI goes low as the result of the effect of CTN on the analog circuitry of the bridge board. (U7 slews, causing the output of comparator U9 to go low.)

This completes the description of logic circuit operation up through the time period designated BURST (at the top of the timing diagram of Figure 6-9). At this point, the counter comprising U3, U2, U8, U13, and U26 is in the following condition: U3 and U2 each contain zero, and the section U8, U13, and U26 contains the count of the number of CP1 (or $\overline{CTN}$) pulses that have occurred.

The up-down integration portion of the measurement cycle is described next. (See interval designated INTEGRATE at the top of the timing diagram of Figure 6-9). Note that signal "S", going low at the end of the BURST, forces U37-8 high, thereby enabling U37-6 to pass pulses from U3-11 to U2-14.

*Counting Cycles of $\overline{UPC}$ and $\overline{DNC}$ (fHz).* Signal $\overline{UPC}$ is a dc logic signal established by a fixed count of 100 cycles of 60 kHz from U27 and is used to establish the fixed time ($T_1$) in which the gate (Q26) for the positive, variable slope of the remainder dual-slope integrator is closed (Q26 is on). Signal $\overline{DNC}$ is a time-variable pulse count for the fixed falling slope of the integrator output. When the falling slope crosses the zero threshold, the count stops, and the pulses counted during this period, $T_2$, together with the previous $\overline{CTN}$ count, constitute the measurement result. DC logic signal $\overline{DNC}$ enables FET gate Q27 of the integrator circuit.

Decade counters U3, U2, U8 and U13, and J-K flip-flop U26-15 keep count of the pulses that determine the UPC and $\overline{DNC}$ time periods. U3 and U2 are only used for UPC-time counting. The J-K flip-flop indicates the "spill", or most-significant-digit +1 count, for the 1-kHz measurement mode of operation, to indicate a 19999 count on the readout display.

For the 120-Hz mode, pin 12 of counter U13, which is the 1-count output of the counter, serves as the "spill" bit for a maximum count of 1999 on the display in this mode of operation.

At the conclusion of the BST count, J-K flip-flop U36 is enabled by J-K F-F's 34, which put a logic 1 on the reset (R) input of F-F36, allowing the F-F to be synchronized and clocked by the next 60-kHz pulse from the oscillator, U27-6.

The falling edge of this pulse causes the Q side of U36 to go to 1. This enables NAND gate U32, which is also connected to the 60-kHz oscillator. This operation syncronizes the oscillator so that a full width 60-kHz pulse, and not part of a pulse, is passed through U32 to the decade counters.

F-F U36, when set, defines signal SUD as going high. This signal enables F-F U26, the $\overline{UPC}$ and $\overline{DNC}$ output NAND gates (U31), and the CP2 (zero threshold crossover signal) input gate, U32-3. Signal SUD also turns on FET gate S3 shown in Figure 4-2 (Q28 in the schematic, Figure 6-4).

Signal $\overline{UPC}$ is forwarded to the bridge board and applied to FET gate $S_Y$ (Q26 on the schematic). The duration of the UPC pulse is determined by 100 counts of the 60-kHz, as counted by U3 and U2. When the 100th pulse is counted, pin 11 of U2 goes low. Since pin 11 is connected to the clock input of F-F U26, and the J-K inputs of this flip-flop are enabled by signal SUD, which is now high, F-F U26 is set, its Q output going to 1. This results in a number of things: It disables $\overline{UPC}$ NAND gate U31-11 (which was previously activated by the $\overline{Q}$ output of U26 and the Q side of U36) and enables $\overline{DNC}$ NAND output gate U31-8, causing signal DNC to go low. It also enables the count-complete (CC) NAND gate (U32-6) and also allows the coupling of decade counter U2 to counter U8, through NAND gate U31-6.

U31-6 is enabled by the Q side of U36, which goes high after pin 11 of U2 goes low. This particular negative-going edge of the 100th UPC pulse at U2-11 does not introduce a count into U8. Immediately thereafter, however, U31-6 is enabled for counting DNC pulses from U2-11. Note that U3 and U2 are automatically in their reset state at the conclusion of the 100th UPC pulse, ready to count DNC pulses.

When U26 is set, signal $\overline{DNC}$, a dc level, goes low at the output of U31-8 (TP13). $\overline{DNC}$ stays low until the downward ramp of the integrator (U10) output crosses zero volts, at which time signal CP2 goes low, producing a count complete (CC) logic-low signal at U32-6. This DNC time period is designated $T_2$ in Figure 4-2.

When CC goes low, the actual measurement process is completed, and the measured value is contained in counter chain U3, U2, U8, U13, and U26. No further counting will take place in this chain until a new measurement is initiated. All of the remaining timing in Figure 6-9, and the remaining circuitry in Figure 6-10 is involved with the processing of the measured value, synchronizing it with the display timing, comparing it with the selected limits of the limit option, etc.

The occurance of the negative edge of CC is, therefore, the point at which an entirely new sequence of operations is initiated on the logic board.

Note that CC going low brings STC low via U37-11 and U33-6. This closes S1 and S2 on the bridge board, thereby discharging C1 and C2 of Figure 4-2. Also, STC low resets F-F's U34; and the resulting low at U34-15 resets U36 at

pin 3, causing U36-15 to go low. This disables U32-11 so that no further 60-kHz pulses can reach U3-14, thereby terminating the counting process (note the resulting low of SUB in Figure 6-9).

Signal $\overline{CC}$ is also delivered to cross-coupled pair U16, which, when set, signifies that a new value (NV) is now present in the counter chain. Signal NV is actually set in time-synchronization with signal $\overline{D1}$, via U16-11 (see Fig. 6-9), where the timing for $\overline{D1}$ (and also $\overline{D2}$, $\overline{D3}$, and $\overline{D4}$) originates from scan oscillator U27-8 (1 kHz). (The 60-kHz from U27-6 and the 1-kHz from U27-8 are asynchronous with each other.) Signal NV is now used to enable the generation of strobe pulses SD3 (strobe data during time D3), and SDL (strobe data into latches U15, U10, U9, U14 and U25).

When SDL goes high (U4-2, U4-4, U4-6, U4-10), the measurement value contained in the BCD counter chain is strobed into latches U15, U10, U9, U14, and U25 and is presented to the inputs of the two dual 4:1 multiplexers, U20 and U23, ready for display. The BCD latch output is also available for data output. (See U18, U19, and U22 at the lower right of Figure 6-10.)

The proper BCD digit is passed from the latches to 7-segment decoder U24, via multiplexers U20 and U23, whose multiplexing control is derived from scan oscillator U27-8 via U21. The outputs of U21 are also decoded in U17 to produce the 4 time states designated $\overline{D1}$, $\overline{D2}$, $\overline{D3}$, and $\overline{D4}$. (See Figure 6-9 and 6-10.) These time states are ultimately fed to Q1, Q2, Q3, and Q4 to activate respective display digits 1, 2, 3, and 4. (Digit 4 is the least significant-right-most digit.)

*Error Signal E.* In the 120-Hz measurement mode (Q20 not conducting), if a count $\geqslant$ 2000 DNC pulses is achieved prior to CC going low, an over-range error, or 'E', condition has occurred. In this case the spill digit, taken from pin 12 of counter U13 (which is high for a count of 1999, and goes low for a count of 2000), causes IC5-8 to go from a low to a high condition. This in turn produces a negative-going edge at U5-6 that sets and latches F-F U6, thereby producing signal E at U6-15.

If measurements are being made in the 1-kHz mode (Q20 conducting), an over-range, or 'E', condition occurs when 20,000 is counted prior to CC going low. In this case the spill digit, occurring at U26-15 (which is high for a count of 19,999, and goes low for a count of 20,000), causes IC5-3 to go from a low to a high. As in the 120-Hz mode, signal E is again produced at U6-15. (See Note 2 of Figure 6-9.)

Signals E and $\overline{E}$ are used for a number of different applications, as follows:

1. To produce an E readout in place of the spill, or 1, digit on the left-most readout display digit, through transistor drivers Q24 and Q11, which are turned on. (Q9 on, holds Q10 off, to inhibit the display of spill 1.)

2. To furnish a low ($\overline{E}$) signal to the rear-panel MEASUREMENT-DATA connector, for use by peripheral equipment to signal an over-range condition.

3. To furnish a high E signal for use by the optional limit comparator to signal an overrange condition and inhibit the comparison. (F-F U6-15 is reset at the start of a new measurement, disabling the overrange-inhibit condition.)

*Display Readouts.* As mentioned previously, the BCD counter chain U3, U2, U8, U13 and U26-15 counts the DNC pulses until the zero crossover signal, CP2, occurs. After this, in time synchronization with the leading edge of the first D4 pulse, which occurs after the negative edge of CP2, the contents of the counter are strobed into latches U9, U10, U14, U15 and cross-coupled pair U25 by pulse SDL. F-F 26-15 contains the spill digit for the 1-kHz measurement mode.

Cross-coupled flip-flop U25, when set, turns on Q22 directly. This causes Q10 to be turned on, activating the one-digit (spill) indicator. If, in this case, the DNC count exceeds 19,999, the E signal is produced, as previously described, which causes Q10 to be turned off by Q9 and Q11 to be turned on. This causes the E symbol to be displayed in place of the "1" digit. Note that the output of pair U25 does not pass through multiplexers U20 and U23.

The BCD values stored in latches U9, U10, U14 and U15 are presented to the inputs of dual 4:1 multiplexers U20 and U23, which comprise four 4:1 multiplexers. The four outputs of each latch are applied to the 4 sections of the multiplexers, one output to each section. The multiplexers furnish 4 output signals simultaneously, corresponding to the 4 BCD bit outputs of a latch. The 4 multiplexers are strobed separately and sequentially by the states of address signals CTR1 and CTR2, so that each numeral is displayed sequentially at the correct digit position of the readout display. (The correct display digit is selected by decoding CTR1 and CTR2 in U17 to produce signals $\overline{D4}$, $\overline{D3}$, $\overline{D2}$, and $\overline{D1}$, which are applied to digit drivers Q4, Q3, Q2, and Q1, respectively.) The multiplexer outputs are applied to BCD-to-seven-segment decoder/driver U24, which decodes the four inputs, 7(A), 1(B), 2(C), 6(D), as shown in the truth table below. Input pin 3 of the decoder is the lamp test (LT) input, and pin 5 is the ripple blanking input (RBI). The latter pin is held at logical 1 at all times.

The decoder outputs for the desired numerals to be displayed are logic 0's. (Refer to Figure 6-10, which shows the association between the decoder letter-designated outputs and the display numeral.) When the output(s) go to 0, the associated transistors Q12-Q18 are turned on, activating the letter-designated, or numeral-segment, lines.

Each line is applied to all LED's of the display. Therefore, it is necessary to enable a particular digit position at the appropriate time, as mentioned previously, to display the stored data correctly. The digit display order is 4-3-2-1, as

TRUTH TABLE SN5446A, SN5447A, SN7446A, SN7447A

| | INPUTS | | | | | | | OUTPUTS | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DECIMAL OR FUNCTION | LT | RBI | D | C | B | A | BI/RBO | a | b | c | d | e | f | g |
| 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| 1 | 1 | X | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 |
| 2 | 1 | X | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 |
| 3 | 1 | X | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 4 | 1 | X | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 |
| 5 | 1 | X | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 6 | 1 | X | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 7 | 1 | X | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |
| 8 | 1 | X | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 1 | X | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| 10 | 1 | X | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 0 |
| 11 | 1 | X | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 |
| 12 | 1 | X | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 |
| 13 | 1 | X | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| 14 | 1 | X | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 15 | 1 | X | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| BI | X | X | X | X | X | X | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| RBI | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| LT | 0 | X | X | X | X | X | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

defined by signals $\overline{D4}$, $\overline{D3}$, $\overline{D2}$, and $\overline{D1}$ from U17. (See Figure 6-9.) Lines K4, K3, K2 and K1 at S03 are activated in this order. These lines strobe the cathodes of the associated LED's.

The timing established by F-F's U21, which produce signals CTR 1 and CTR 2, is shown in Figure 6-13, the comparator schematic diagram. F-F's U21 are simply wired as a divide-by-four count down pair.

In addition to producing signals that enable the appropriate LED's, signals $\overline{D1}$ thru $\overline{D4}$ are also used for some other functions, as illustrated in timing diagram, Figure 6-9. Signal D3 is applied, through inverter IC12-2, to NAND gate U11-8, to produce strobe signal SD3 (strobe data during $\overline{D3}$ time), under the following conditions. Since signal CC and $\overline{D1}$ have set cross-coupled flip-flop U16, signal NV is a logic 1 level at pin 11 of U11-8. F-F U6-11 was set (at pin 7) when signal up-count (UPC) went low during the counting of UPC pulses (Figure 6-9). U6 remains set, with its Q output at a logic 1 level, enabling pin 9 of U11-8 so that the next inverted $\overline{D3}$ pulse can produce signal $\overline{SD3}$.

F-F U6 gets reset when pulse $\overline{D2}$ goes low, which occurs after $\overline{D3}$ goes low. $\overline{D2}$ is inverted and applied to gate U11-12. Since a logic 1 level (signal NV) is applied to pin 2 of the gate, the next positive pulse from the scan oscillator (signal SCAN), which is one-half the pulse width of the "D" signals, causes the output of U11-12 to go to 0 and reset F-F U6-11. The flip-flop remains reset until a new measurement cycle occurs.

Signal $\overline{SD3}$ is applied to U39, triggering the timer which, in the REPETITIVE MODE, produces a "TIME" signal at U16-8, the duration of which is determined by timing resistors R500 and 502 on the MEASUREMENT MODE front-panel switch. Signal "TIME," while low, inhibits one-shot IC38. The positive-going trailing edge of signal TIME triggers one-shot U38 to initiate a new measurement sequence. (See Note 3 in Figure 6-9.) The duration of signal TIME is the time allowed for a value to be displayed and for a limit comparison to be made. This time can be varied, as desired, to allow data to be recorded, etc. The time can be varied from approximately 1/4 s to 10 s.

Signal SD3 also serves as a strobe signal for external equipment to signify that data is available for recording, actuate handlers, etc.

Signals $\overline{D4}$ and $\overline{SDL}$ are also forwarded, via S04, to the limit comparator to provide gating and timing signals for the comparator. At the time that multiplexers U20 and U23 read out data for the selected digits, the data is also made available to the comparator, via S04, as signals A0 thru A4, A4 being the "spill" digit for 1-kHz operation.

Decimal point indications for the readout display are established by the front-panel RANGE switch. The switch applies +5 V via S02-12-13, and -14 to the appropriate 75-Ω current limiting resistor, R56, R68 and R69, and to the readout digits via the appropriate decimal-point line (DP2-DP4). The switched +5 V is also routed through transistor drivers Q23, Q26, and Q25 to the rear-panel DATA connector, via non-inverting buffers U30-12, U30-8, and U30-10, respectively. When the +5 V is applied to one of the 3 transistors, the transistor is turned on, producing a low output at the DATA connector.

*Output Signals.* In addition to providing timing signals for the bridge board, signals produced on the logic board are also furnished to the optional limit comparator, if installed, and to the rear-panel DATA connector.

*Limit Comparator Signals.* The signals furnished to the limit comparator are shown at the top of Figure 6-10, at connector S04.

As described previously, signals A0 thru A4 are the measurement-value data bits obtained from the multiplexers when they are strobed at the desired time. Signals CTR1 and CTR2, which are used on the logic board to establish the timing of signals D1-D4, are also supplied to the comparator where they are used to establish and initiate additional sequenced timing events. For example, when CTR1 and CTR2 are both high on the comparator logic board (1685-4750) they signify that time state 1 (the time during which signal D1 is active) has just been completed and that time state 4 (defined by D4 active) is just beginning. See Figures 6-9 and the timing diagram on Figure 6-12.

Signal $\overline{SDL}$ at connector S04, as mentioned previously, defines that the measurement is completed and that data is now available for display. Timing signal D4 is also forwarded to the comparator, for gating purposes.

In addition, the overrange, or error, signal, "E"; scan oscillator signal "SCAN"; and the "RESET" signal are also supplied to the comparator. These signals were described previously.

A signal designated DQL is also sent to the comparator via S04. This signal is a logic 1 level if the D measurement exceeds the selected limit, or the Q measurement falls below the selected limit, determined by the setting of the front-panel D-Q dial. Signal DQL is taken from the high-D lamp.

The "REMOTE START" signal at S04 is an input signal from the comparator, the positive-going edge of which turns on Q21 to initiate a new measurement at U38.

There are two other connections. These are designated INTERFACE 1 and INTERFACE 2. These are through connections from S01 to S04 that allow peripheral equipment connected externally to the comparator. (e.g., a mechanical parts handler) to interface directly to other peripheral equipment; for example, a GR Type 1785 printer connected to the rear-panel DATA output connector.

*Output Data Connections.* The data and control output signals available to run peripherial equipment and the control-signal input provisions available from peripheral equipment are described in Section 2 of the manual.

Note that the BCD data outputs shown on the lower right on the schematic (Figure 6-10) are taken from latches U9, U10, U14, U15, and U25-2. Therefore, the least-significant-digit output at S01-2 is derived from U15-5, and the most-significant-digit output at S01-14 is taken from U14-16; the MSD+1 output is taken from U25-2. It is important to note that U18, U19, and U22 are plugged into sockets on the board, so that these IC's can be easily replaced if positive-true output logic levels are desire instead of the negative-true logic output supplied with the instrument. All DATA output lines are open-collector, with a 30-V breakdown limit.

## 4.3 LIMIT COMPARATOR

### 4.3.1 General

The optional Limit Comparator is comprised of two circuit boards, the type 1685-4750 limit option board 'A' and the type 1685-4760 limit option board 'B'; a front-panel assembly; and various cables (both separate and attached to the front-panel assembly) that plug into the comparator boards and connectors mounted on the chasses. The cables interface the panel, comparator boards, and the meter logic and bridge boards. Figure 6-3 is a block diagram showing the interconnections between the comparator's components and the meter.

The general principle of the comparator is to take data from the meter after the measurement is completed and then compare the data, first against the low limit (established by means of the comparator LOW LIMIT digi-switches) and then against the high limit (established by means of the HIGH LIMIT switches).

The comparison is first made for the two-most-significant digits, MSD+1 and MSD. This involves a 5-digit comparison for the first compare operation. Four-digit comparisons are made for the following 3-numeral comparisons (3 rightmost readout digits). Although comparisons are made for each digit, the results of the particular comparison are not used if a more significant digit is found to be outside the selected limits.) The comparisons are done during time state signals D4, D3, D2, and D1, respectively. (These signals, or time-states, are described in para. 4.2.4, and are shown in Figures 6-9 and 6-12.)

Both the low-limit comparison and high-limit comparisons are made even if the low-limit comparison, made first, is unacceptable. Multiplexers on the 'B' board switch the selected high- and low-limit values to a 5-bit comparator on the 'A' board in which the limit comparisons are made. The central part of the limit-comparator option is the 5-bit TTL/MSI 9324 IC comparator. The IC makes the comparison for both the low and high limits, with the correct limit data for each digit being switched to the IC comparator at the proper time by the multiplexers.

### 4.3.2 Comparator Board B (P/N 1685-4760)

Figure 6-13 shows the schematic of the 'B' board and includes the wiring representations of the LOW- and HIGH-LIMIT front-panel digi-switches, including the BCD outputs (1-2-4-8) of each switch.

The board includes a pull-up resistor for each line, and 4 SN74153 dual 4-line-to-1-line multiplexers that switch their inputs to the 5-bit comparator on the comparator 'A' board.

The leading edge of pulse $\overline{SDL}$ activates the comparator. (See Figure 6-12.) When $\overline{SDL}$ occurs, the output of cross-coupled pair (U15-11 (designated signal GATE), enables strobe pulses for comparator U2. These pulses, designated COMPARE, are initiated in time synchronization with the positive transitions of the SCAN signals. Details on the actual comparison operation are given further on in this paragraph.

Although U6 is enabled by the leading edge of $\overline{SDL}$, U6 will not change state until the next time $\overline{CTR2}$ goes low at U11-8. From the timing diagram, it is obvious that the first 4 of the 8 COMPARE pulses occur before U6 changes state (before signal COMP-4 goes high). Then the last 4 COMPARE pulses occur. Referring to Figure 6-13, the inputs to the multiplexers from the LOW-LIMIT digit-switches are selected when $\overline{COMP\text{-}4}$ is low. (A low at pin 15 of each multiplexer enables input pins 10,11,12, and 13.) Conversely, the inputs to the multiplexers from the HIGH LIMIT digit-switches are selected when COMP-4 is low. (A low at pin 1 of each multiplexer enables input pins 6, 5, 4, and 3.) Figure 4-13 shows a functional block diagram of the multiplexer.

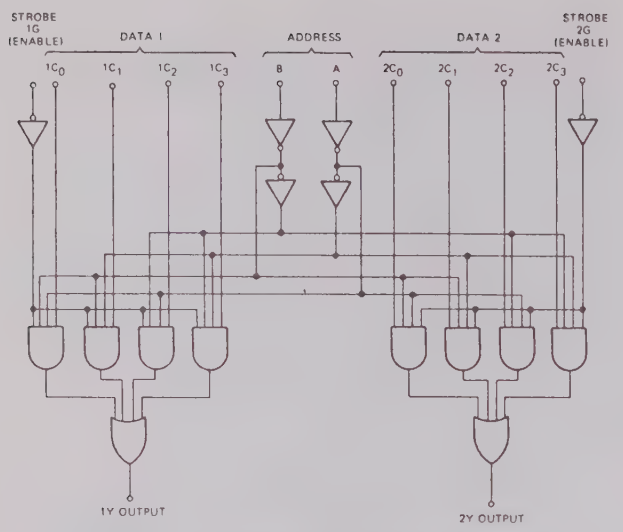



**Figure 4-13. Multiplexer functional block diagram.**

From the timing diagram in Figure 6-12, it is clear that $\overline{SDL}$ goes low in time synchronization with $\overline{CTR1}$ and $\overline{CTR2}$ going low (during time state 4, when D4 is active). These two signals are applied to pins 14 and 2 of each multiplexer; when these two pins are low, multiplexer input pins 10 and 6 are selected. (The levels at pins 1 and 15 then determine which of the levels (pin 6 or 10) is passed to U1.) Thus, the first digit to be multiplexed after the arrival of $\overline{SDL}$ is the MSD from the LOW-LIMIT digit-switches. This MSD is strobed into the comparator (U2 on the 'A' board) by the first COMPARE pulse. As signals $\overline{CTR1}$ and $\overline{CTR2}$ continue, successive digits from the LOW-LIMIT switches are selected, the LSD being strobed into the comparator by the fourth COMPARE pulse.

Signal COMP-4 changes state after the fourth COMPARE pulse, so that the second time that $\overline{CTR1}$ and $\overline{CTR2}$ go through their sequence to enable the multiplexers during time periods D4, D3, D2, and D1, respectively, the digits from the HIGH-LIMIT switches are selected (MSD first; LSD last). All 4 multiplexers are strobed in the same manner, providing four data outputs to the A board via U1.

Note that signals $\overline{CTR1}$ and $\overline{CTR2}$ are always in the process of exciting the multiplexers, so that the multiplexers are always producing an output of some type; however, in the absence of any COMPARE pulses, any such outputs are ineffective and produce no results.

The MSD+1 line from the digit-switches (high and low) are not multiplexed. They are applied directly to the 5-bit comparator (U2) via NAND gates U16-12 and U16-6, where they are strobed through only during time state D4.

### 4.3.3 Comparator Board A (P/N 1685-4750)

*Inputs.* Figure 6-12 is the schematic of the A board. This board performs the comparison between the measured value and the high and low limits established by means of the respective comparator digit-switches.

The RESET pulse that occurs at the beginning of a measurement sequence resets the board circuitry. After the component under test is measured, signal $\overline{SDL}$ is produced on the meter's logic board. This signal strobes data stored in the decade counters into the associated latches for use by multiplexers on the logic board. Signals CTR1 and CTR2 on that board sequence the data out of 2 multiplexers similar to ones used on the comparator B board. This data is strobed out on 4 parallel lines. The data on the lines is the BCD equivalent of one numeral of the display. The 4 NAND gates of each of the 4 multiplexer sections on the logic board are strobed sequentially, once each during times D4, D3, D2, and D1 by the various interactions of signals CTR1 and CTR2 as described previously. This provides BCD equivalents each time for one display digit, for a total of 4 digits.

In addition to furnishing these data to the readout displays, the logic-board data are routed to the A board, via S04, over lines designated A0 thru A3. Another line, A4, is the most-significant-digit +1 line, or "spill" line, taken from a cross-coupled F-F on the logic board. These lines are applied to 5-bit comparator U2 on the A board.

The lines from the low and high-limit multiplexers on the B board are applied to pins B0 thru B3 of the 5-bit comparator, via connector S03. The MSD+1 digits from the high- and low-limit digit-switches are applied to comparator input B4, via NAND gates IC16-12 and -6 and IC 15-3. These lines are not multiplexed, but are selected via the NAND gates by the same signals that enable the B-board multiplexers for high- and low-limit comparisons, as described earlier.

Signal GATE enables one-shot IC12, which allows signal SCAN from the comparator logic board to produce pulses approximately 1 $\mu$s wide that are fed to U5-6 and U5-8. If there is no overrange condition (signal E low) and the limit comparator is not disabled either by its front-panel LIMIT-OFF enable-disable switch or by a logic 1 applied to the rear-panel connector LIMIT DISABLE pin, IC-5-8 enables the 5-bit comparator by applying a logic 0 pulse to pin 1 of U2. This is signal COMPARE shown in Figure 6-12. Eight COMPARE pulses are applied to the comparator, as described previously.

When the 5-bit comparator is enabled by the COMPARE pulses from gate IC5-8, corresponding digits of the measured-value-data and the digit-switches data are compared with each other in the IC.

*Five-Bit Comparator.* The 5-bit comparator is a Fairchild 9324 (or equivalent) high-speed expandable, 5-bit comparator that furnishes a comparison between two 5-bit words and gives three outputs: "less than", "greater than," and "equal to". A high level at pin 1 forces all three outputs low. A low level enables the comparison function.

Figure 4-14 shows the schematic diagram of the comparator. The measured-value inputs come in on the "A" pins; the digit-switch limits come in on the "B" pins. Signal $\overline{E}$ input (active low enable) is signal COMPARE, which

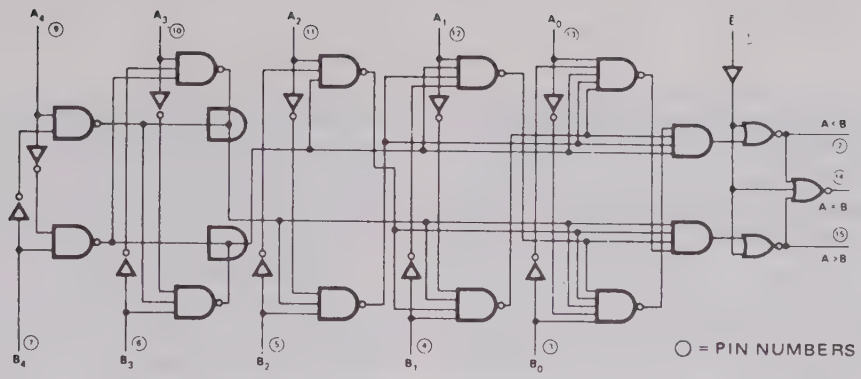



**Figure 4-14. Comparator logic diagram.**

goes low eight times during a comparison. The first comparison (during D4 time) is a 5-bit comparison consisting of the MSD+1 digit and the 4 bits that comprise the MSD Then 4-bit comparisons are made for the 3 remaining digits. (This makes a total of 4 comparisons for the low-level limit.) A comparison is then made in the same manner for the high limit (regardless of whether the low-limit was acceptable or not) for a total of 4 high-limit comparisons, or a total of 8 comparisons for the low and high limits.

The low-limit operation compares A inputs (data) against the B (limits), normally to find if A is greater than B (A > B). Then the high-limit comparison is made to find if A is less than B (A < B).

The A>B (pin 15) and A<B (pin 2) outputs of the comparator are fed to 4 cross-coupled pairs via NAND gates U9-8, U10-8, U9-6, and U3-8. These gates feed, respectively, cross-coupled pairs U5-12 and U4-6, U10-11 and U10-3, U10-6 and U4-8, and U3-11 and U3-6. Outputs from these cross-coupled pairs are used to light appropriate lamps and produce status signals indicating the results of the comparison process. Pins 2 and 15 of U2 normally reside at logic zero (low). A positive-going pulse occurs at pin 15 if A>B; a positive-going pulse occurs at pin 2 if A<B. The width of the pulse is defined by the width of the COMPARE pulse at U2, pin 1.

The cross-coupled pairs driven by the A>B and A<B outputs from U2 are mandatory in the circuit because U2 performs only a digit-by-digit comparison of its two BCD input numbers. Thus, if A = 1.719 and B = 1.284, and the values are compared from MSD to LSD (in this order), the first (MSD) comparison will produce no pulse at either output of U2. The second digit comparison will obviously produce an A>B pulse, the third an A<B pulse, and the last (LSD) comparison an A>B pulse. Since an A > B output is produced prior to any A < B output, it clearly signifies that the overall number A is greater than the number B. The cross-coupled pairs driven by U2 store this type of information during the comparison process.

*Low-Limit Comparison.* The low-limit process can be followed through on the logic diagram, Figure 6-12. At the beginning of a measurement sequence, the RESET pulse sets U4-6, U10-3, U4-8, and U3-6 high. During the low-limit comparison, signal COMP-4 is low, inhibiting U9-8 and U10-8, leaving only U9-6 and U3-8 capable of responding to A>B and A<B output pulses from U2. Clearly, if an A>B pulse occurs before an A<B pulse, the low-going pulse produced at U3-8 sets cross-coupled pair U3-11 and U3-6, so that U3-6 goes low, thereby inhibiting any subsequent A<B pulse from getting through gate U9-6. (The cross-coupled pair driven by U9-6 cannot be set when A>B occurs overall number A is less than the number B, and that a low-limit failure has in fact occured.) Thus, since the cross-coupled pair driven by U9-6 cannot be set when A>B occurs before A<B, the failure condition cannot be produced; the low-limit comparison operation is a success.

If, however, an A<B pulse occurs before an A>B pulse, U9-6 goes low, setting cross-coupled pair U10-6 and U4-8, to produce the low-limit failure condition. Note that any subsequent A>B pulse from U2 will set cross-coupled pair U3-11 and U3-6, thereby preventing U9-6 from passing any more A<B pulses; however, this action is meaningless since the failure condition has already been produced.

*High-Limit Comparison.* The high-limit comparison operation is performed in a manner similar to the low-limit comparison. The only significant difference is that after the 4 low-limit COMPARE pulses, signal COMP-4 goes high. (Therefore, $\overline{\text{COMP-4}}$ goes low.) Under these conditions, NAND gates U9-6 and U3-8 are gated off, and NAND gates U9-8 and U10-8 are enabled. The high-limit failure condition is produced by an A>B pulse occuring before an A<B pulse, and the status is stored in cross-coupled pair U5-12 and U4-6. Note that U5-12 has an additional input at pin 2. This input, from U5-6, is normally dc high, thereby enabling gate U5-12. If there is an over-range condition, however, signal E, applied to the A board at S04, pin 4, from the logic board, goes from a logic low to logic high. This action disables U5-8 via U1-10, so that no COMPARE pulses can be produced. However, a negative going pulse is produced at U5-6, which forces the high-limit failure condition to be set at U5-12 and U4-6.

*Result of the Comparison Process.* Note that if neither a low-limit failure condition or a high-limit failure condition is produced, U4-6 and U4-8 will reside high at the conclusion of the overall comparison process; U5-12 and U10-6 will be low. The results of the comparison process are fed from these 4 outputs to the various output functions of the board.

Consider the function of one-shot U8. A failure condition at U4-8 will produce a negative-going edge at U8-3; similarly, a failure condition at U4-6 will produce a negative-going edge at U8-4. In either case, one-shot U8 will be triggered, to produce an output pulse at U8-6 that enables U3 at pin 1 for approximately 0.25 s. During the 0.25 s, U3-3 delivers a 250-Hz signal (1 kHz ÷ 4) to transistor Q7, and subsequently to pin 6 of the rear-panel output connector (S05) through a 10-Ω, 1/2-W resistor. Pin 6 is intended to drive some type of audio alarm (e.g., a miniature 8-Ω or 10-Ω speaker) connected between pin 6 and ground of the instrument. Thus, in a manual sorting operation where an operator may be testing a large number of parts of the same value, the great percentage of which are good, the occasional failure will be vividly brought to attention so that the operator responds accordingly. The 10-Ω, 1/2-W resistor feeding pin 6 renders the pin short-circuit proof to ground (i.e., prevents the burn-out of Q7). Diode CR2 prevents any possible inductive transients at pin 6 from reaching and damaging transistor Q7.

The $\overline{\text{LOW}}$ and $\overline{\text{HIGH}}$ output functions at the rear connector (at S05 pins 14 and 17 respectively), as well as the LOW and HIGH front-panel indicator lamps (DS3 and DS4), are activated in the following manner. A low-limit failure produces a high at U10-6. This turns on Q1, which brings S05, pin 14, low and lights the red LOW-LIMIT failure lamp on the front of the Limit Option module. Similarly, a high-limit failure sets U5-12 high, thereby turning on Q2 to activate the HIGH output functions. Normally, on a failure, either a high-limit failure or a low limit failure is expected, but never both. However, both failure conditions can and will be produced if the low-limit value dialed in on the digit-switches is higher than the dialed-in high-limit value, and the measured value lies in between these two limit values.

The results of the comparison process at U4-8 and U4-6 are fed to two of the inputs to NAND gate U14-6. Therefore, if either of these lines is low, signifying a failure, the output of U14-6 will be a guaranteed high, thereby forcing U1-6 low and ensuring that Q4 is off. This inhibits the front-panel GO indicator lamp from being lit and prevents the $\overline{\text{GO}}$ output line at S05 pin 16 from going low. (A low signifies the "GO" condition — negative-true logic.) The Q4 output is also fed to the base of Q9; if Q4 is off, Q9 is also turned off. Q9 drives the PASS lamp on the P1 test fixture, via S06, pin 4, from the A board.

If, however, a failure condition is *not* produced, then U4-8 and U4-6 remain high at all times during and after the compare operation. Therefore, one-shot U8 never fires, and the inputs at U14-3 and U14-4 keep gate U14-6 in an enabled condition. Note that this does not produce a GO condition; it merely enables a GO condition. There are two other conditions that must be met before a GO condition can be produced (before Q4 can be turned on). First, the DQL line input to the board must be low. (A high, signifying a HID failure on the bridge board, would turn on Q5 via latch IC15-8, and, therefore, hold Q4 turned off.) Second, if the above conditions are met, Q4 is allowed to turn on via U14-5 only after U6-8 goes low (i.e., after signal DONE is produced — see the timing diagram in Figure 6-12). Thus, only after the full completion of the comparison operation can a "GO" indication, if any, be produced.

Note that signal DQL, in addition to operating Q5, via latch IC15-8, also turns on Q3 in the presence of a HID fault condition, thereby turning on the front-panel HIGH-D lamp (DS2) and bringing the rear-panel HID line low at S05, pin 15. Also note that the base of Q3 is gated by the DONE signal, via U1-12. Therefore, even though the high-D information is available from the bridge board long before the comparison operation takes place, this information is not made available externally until the comparator results are also available.

An asynchronous failure condition, FAIL, (i.e., not gated by signal DONE) is available at rear-panel connector S05, pin 2 (a low signifies a failure condition); this signal (produced at U14-8 by a low on any one of its 3 input lines) is also fed to Q8 which, when turned on, lights the FAIL lamp on the P1 test fixture.

Output signal $\overline{\text{BUSY}}$ is normally high and goes low soon after signal DONE is produced (when both inputs to U7-11 go high—see timing diagram). Therefore, signal $\overline{\text{BUSY}}$, when low (negative true), can be used to signal externally connected equipment that the results of the comparison process are now complete and are available as dc levels at the rear panel output connector, and that these signals will not change while BUSY is low. Signal $\overline{\text{BUSY}}$ is reset (goes high) when a new measurement sequence is initiated.

The line designated CLAMP, at S05, pin 5, is *not* an output signal. Pin 5 is to be tied to the V+ terminal of an external voltage source, where this source is the one used to power the relays that may be connected to S05-14, S05-17, etc. (The negative side of the source is connected to instrument ground.) Refer to Section 2 for details.

*External Signals.* Two connectors are available for the transfer of data and control signals between the comparator and external equipment devices. The PASS and FAIL signals are furnished to rear-panel connector J7 for use with the Test Fixture PASS-FAIL indicator lamps (or other applications, as desired; refer to Section 2). The signals are not routed directly to J7 from the circuit board. They are routed via connector J06, on the side of the chassis, to J7.

Other signals are available via connector S05 at the rear of the circuit board. The connector is a 24-pin Amphenol-type connector available to the user.

Most of the signals available via the connector were described in the previous paragraphs. Section 2 contains a list of the signals and describes their functions. Details are also given on mating connectors.

Lines INTERFACE 1 and INTERFACE 2 at the rear-panel comparator connector comprise two independent copper

paths between this comparator connector and the rear-panel connector of the main instrument. This provides a means whereby external equipment connected to each can directly interface with one another. A positive-going transition of signal REMOTE START can be used as an alternate means to start a measurement operation via an external device connected to comparator. The LIMIT DISABLE signal at S05, pin 1, is an input signal to the A board which, when pulled high, turns on Q6, thereby performing the same function as switch S11 in its OFF position — that is, inhibiting the generation of COMPARE pulses at U5-8.

### 4.4 POWER SUPPLY.

The instrument's power supply furnishes regulated +15 and −15 V for the analog circuits and regulated +5 V for the logic circuits. The power supply is comprised of a transformer rectifier bridge assembly (5 V), mounted in the left rear of the chassis; 4 separate rectifiers on a transformer terminal board; a power supply board, P/N 1685-4730, containing two regulators; (+15 V and −15 V); and a 5-V regulator. The power supply board is mounted in front of the transformer and rectifier (bridge) assembly, under a metal cover secured by 3 screws. The 5-V voltage regulator package (U501), which is a part of the +5-V supply, is mounted on a heat sink at the rear of the chassis. The bridge rectifier (CR501-CR504) for the 5-V supply is mounted at the rear of the power supply board.

The rectifiers for the ±15-V section of power supply are mounted on a terminal board assembly on top of the transformer. The assembly contains rectifiers CR6-CR10 and some resistors. Filter capacitors (C501, C503, and C504) for the supplies are below the power supply board.

A capacitor (C505) connected to the input of the 5-V regulator and one (C506) connected to the output are soldered to the regulator-package pins.

The tapped power transformer (T1) and associated selector switch permit selection of a wide range of operating voltages. The switch positions and selections, in order, are OFF, 90-110 V, 104-127 V, 180-220 V, 194-236 V, and 207-253 V. Figure 4-13 shows the transformer configuration for each power range.

A connection from a full-wave rectified output of the transformer is made to the oscillator on the bridge board. This is done via WT's 7 and 18 and allows synchronization of the oscillator with the line voltage, when the desired oscillator 120- or 100-Hz oscillator frequency is twice that of the line frequency.

Regulation for the +5-V supply is furnished by a National Semiconductor type LM 323K 3-A, 5-V positive regulator, mounted on the heat sink at the rear of the chassis. The regulator is a 3-terminal regulator and is virtually blowout proof; it provides current limiting, power limiting and thermal shutdown. A 1-$\mu$F capacitor is used on the input, since the regulator is mounted more than 4 inches from the filter capacitor. A capacitor at the output reduces load transient spikes that may be created by fast switching logic; it also can swamp out stray load capacitance. Maximum output voltage is 5.25 V, minimum 4.75 V.

The main element in the ±15 V supply is a Silcon General type SG3501 dual-polarity tracking regulator that furnishes balanced ±15-V outputs. The regulator is factory-set and provides thermal shutdown, current limiting, and power limiting.

The package regulates the negative voltage, and the positive output tracks the negative. Negative regulation is accomplished by providing a constant-voltage reference for the negative error amplifier in the package; the reference input to the positive error amplifier is grounded. This latter amplifier forces its other input, which is the center-tap between equal resistors, to also be at zero volts, thus requiring the positive output to be equal in magnitude but opposite in polarity to the negative output. The tracking will hold all the way from approximately 1 V above the reference voltage to a maximum value of about 2 V less than the input supply voltage.

Power transistors Q1 and Q2 are connected to the package, along with other components in the configuration shown in the schematic, to allow additional current handling capability. The 100-ohm base-to-emitter resistors, R1 and R2, provide a path for the regulator standby current; base-to-ground capacitors C5 and C6 minimize the risk of oscillation. The WT's designated at the outputs of the supplies are located on the power supply board.

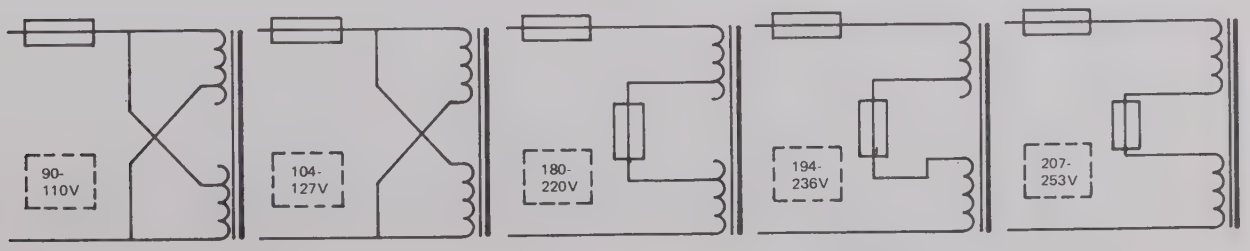



**Figure 4-15. Elementary transformer primary schematic.**

# Appendix A

# An AC-DC Ratiometer and Its Use in a *CRL* Meter

HENRY P. HALL, SENIOR MEMBER, IEEE

*Abstract*—An impedance meter is described which measures dc resistance and ac capacitance and inductance. It uses an ac–dc ratiometer capable of high accuracy and good noise immunity. The ratiometer is a combination of a dual-slope integrator and an integrating phase-sensitive detector. The ratio, which is displayed on a counter, is the number of denominator signal samples required to offset a prescribed number of numerator samples. The remainder output, if important, can be evaluated by a simple dual-slope integrator to provide the readout digits of lesser significance. The same circuit is used for both ac and dc ratios and could be used to determine the ratio of the average value of an ac voltage to a dc voltage.

## Introduction

AUTOMATIC balancing bridges, both ac and dc, which give an accuracy better than 0.1 percent have been designed. However, they tend to be expensive. They require precision adjustable elements (usually digital-to-analog converters) and considerable logic circuitry. In general, they are also slow or susceptible to noise. In the usual successive approximation balance, the decision to use each bit must be made with certainty, and there are many such decisions to make. To get high speed, these decisions must be quickly made and are, therefore, subject to a wide bandwidth of noise.

A meter that makes just one voltage-ratio measurement can use the full allowed measurement time for this measurement. Therefore, the signals could be averaged or integrated much longer, greatly reducing the effect of noise. However, meters, particularly ac meters, are usually less accurate than bridges, because of errors in the voltage ratio measurement.

After a brief description of "half-bridge" circuits that could be used in a bridge or meter, this paper describes an ac-dc ratiometer capable of good accuracy and noise immunity.*

## Half-Bridge Circuits

The basic circuit of Fig. 1 provides two output voltages whose ratio is proportional to $Z_X/R_s$, where $Z_X$ is the unknown impedance, and $R_s$ is a ratio arm of known value. This circuit was chosen because it makes a good four-terminal guarded (ground is guard) measurement of $Z_X$ if the series and shunt lead impedances are of reasonable value, and if the amplifiers have good characteristics.

In a dc resistance bridge two "arms" or networks (one adjustable) would be connected to the half-bridge outputs in such a way that the sum of the currents from these two networks would be zero at balance. In an automatic bridge, the adjustable element is usually a digital-to-analog converter. A dc meter could use a dual-slope, or "up-down," integrator [1], [2], which can be quite accurate.

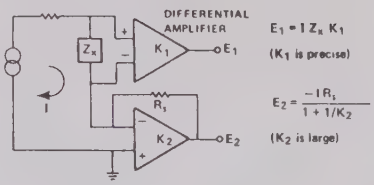



Fig. 1. Basic half-bridge containing two arms $Z_X$ and $R_S$.

An ac bridge would require two adjustable elements to balance both inphase and quadrature voltage components. An ac meter could use two phase-sensitive detectors to provide dc outputs, which could be applied to a dual-slope integrator. It is these phase-sensitive detectors that usually limit the accuracy of ac impedance meters as will be discussed in the next section.

In an ac impedance meter, the signals are phase shifted so that the two outputs are inphase when a pure reactance is being measured. In the capacitance measurement circuit of Fig. 2, this could be done by integrating one signal or differentiating the other. However, integrators enhance low-frequency noise, and differentiators enhance high-frequency noise. Therefore, two bandpass networks are used, which are similar except for the connections of $R_a$ and $C_a$. The ratio of the transfer functions of these two circuits is $j\omega R_a C_a$, giving the required 90° phase shift. (Since only the ratio $E_1/E_2$ is desired, the common part of the transfer functions $f(\omega)$ cancels out.)

If the unknown capacitor in Fig. 2 has loss, and the effective series value of capacitance $C_{xs}$ is desired, then

$$E_1 \sim I\left(R_x + \frac{1}{j\omega C_{xs}}\right) j\omega R_a C_a$$

$$E_2 \sim IR_s.$$

If $E_{apb}$ is defined as the component of $E_a$ inphase with $E_b$, then

$$E_{apb} = \text{Real}\left[\frac{E_a}{E_b}\right] \left|E_b\right|$$

It is easy to see that

$$\frac{E_{2p2}}{E_{1p2}} \sim \frac{R_s C_{xs}}{R_a Ca}.$$

Manuscript received May 7, 1973; revised July 9, 1973. This paper was presented at the 1973 Electrical and Electronic Measurement and Test Instrumentation Conference (EEMTIC), Ottawa, Ont., Canada, May 15–17.

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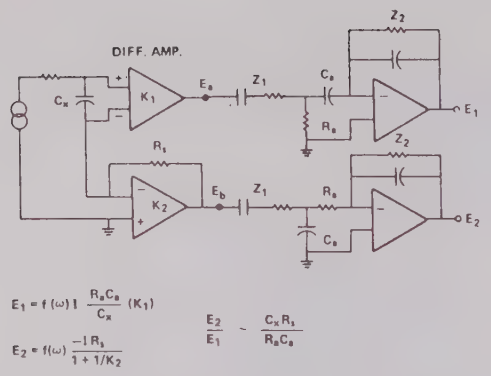
* The accuracies noted in this appendix are examples only and do not apply to the 1685 Impedance Meter.




$$E_1 = f(\omega)\,1\,\frac{R_aC_a}{C_x}\,(K_1)$$

$$E_2 = f(\omega)\,\frac{-1\,R_1}{1 + 1/K_2}$$

$$\frac{E_2}{E_1} \sim \frac{C_xR_1}{R_aC_a}$$

Fig. 2. Capacitance half-bridge with networks to bring outputs inphase.

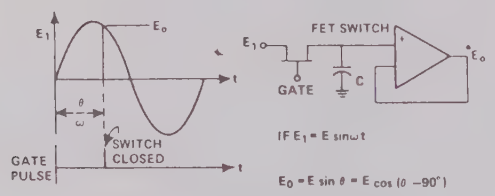



Fig. 3. Sample-and-hold detector.

If the effective parallel capacitance $C_{xp}$ is desired

$$Z_x = \frac{1}{G_x + j\omega C_{xp}}$$

$$E_1 \sim \frac{j\omega R_aC_a}{G_x + j\omega C_{xp}}$$

$$E_2 \sim IR_s.$$

It is easy to show that

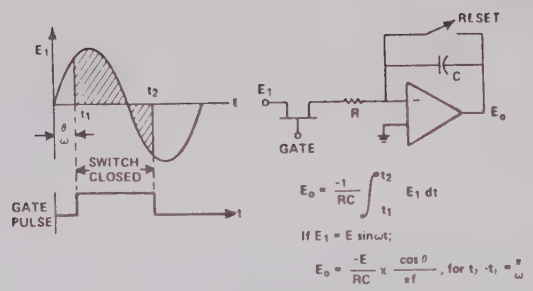
$$\frac{E_{2p1}}{E_{1p1}} \sim \frac{R_sC_{xp}}{R_aC_a}$$

For inductance measurements, the two phase-shifting networks are interchanged, and again, either the series or the parallel quantity inductance could be measured by selection of the proper phase reference.

## Phase-Sensitive Detector Limitations

There are many types of phase-sensitive detectors, but most of them can be classified as either the sample-and-hold (or keyed) type or the integrating type.

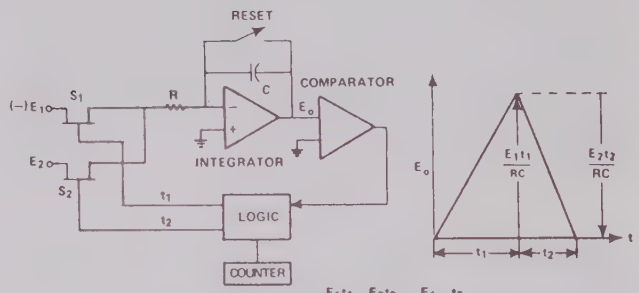
The sample-and-hold type of Fig. 3 is particularly susceptible to noise for any undesirable voltage at the instant of the sample is directly added to the output or, in other words, an impulse sample has an infinite noise bandwidth. Lengthening the sample time or repeating the sample has no beneficial effect, for the output voltage is that of the last instant of the last sample (unless some averaging elements are added). This circuit does not attenuate harmonics of the signal at all; the peak value of any harmonic can be added to the output.




$$E_o = \frac{-1}{RC}\int_{t_1}^{t_2} E_1\,dt$$

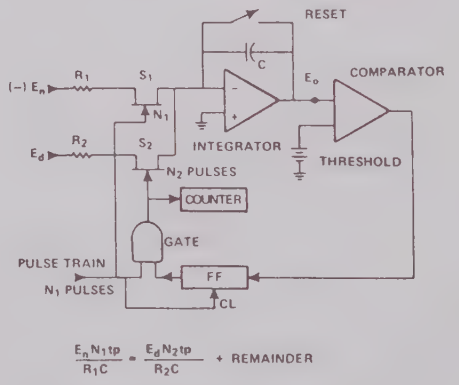
$$E_o = \frac{-E}{RC} \times \frac{\cos\theta}{\pi f}, \text{ for } t_2 - t_1 = \frac{\pi}{\omega}$$

Fig. 4. Integrating detector.




$$\frac{E_1t_1}{RC} = \frac{E_2t_2}{RC} \; ; \; \frac{E_1}{E_2} = \frac{t_2}{t_1}$$

Fig. 5. Dual-slope integrator and output waveform.




$$\frac{E_nN_1tp}{R_1C} = \frac{E_dN_2tp}{R_2C} + \text{REMAINDER}$$

Fig. 6. Modified dual-slope integrator where pulses $N_1$ and $N_2$ have the same pulsewidth $t_p$.

The main advantage of this circuit is that the output voltage is independent of the value of the hold capacitor as long as it is of reasonable value, and thus it need not be precise or stable.

The integrating-type detector (Fig. 4) is much less susceptible to noise because the signal is averaged over a full half-cycle. Furthermore, the sample may be repeated many times and the output is the total average, giving a narrow noise bandwidth. Also, each single sample is immune to even harmonics of the signal and attenuates odd harmonics at a rate of 6 dB per octave.

Unfortunately, the output of the integrating detector is inversely proportional to the value of the capacitor so that the calibration of a meter using two such detectors would depend upon a capacitance ratio. While all capacitance bridges and

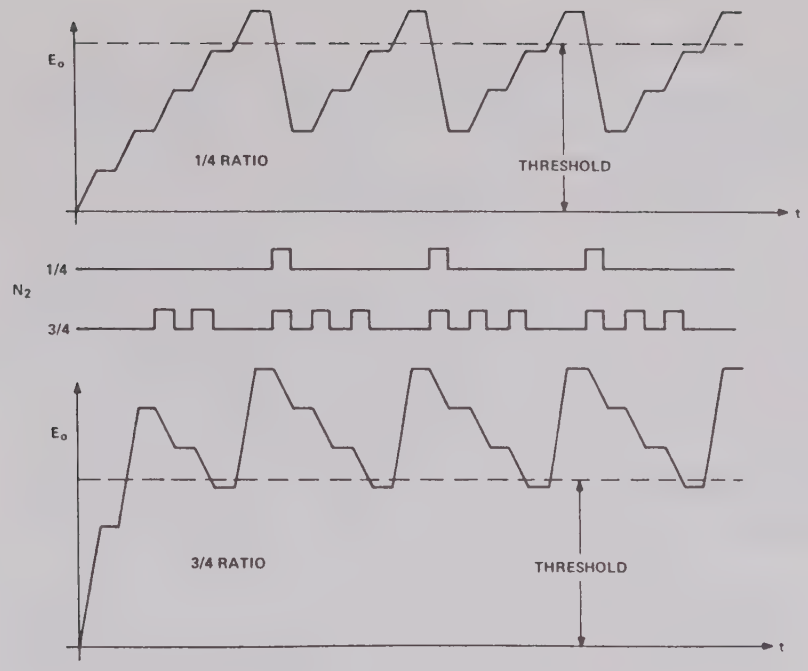



Fig. 7. Integrator output voltage waveforms of modified dual-slope integrator of Fig. 6.

meters (of the ratio type) depend upon a precise capacitance standard, in precise bridges these are low-valued air or mica types. The integrating capacitors are quite large so that air capacitors are entirely impractical and mica very expensive. Moreover, integrating capacitors must have low dielectric absorption, and mica types are poor in this respect. Capacitors of the required stability, value, and low absorption are expensive.

## Dual-Slope Integrator

The dual-slope integrator [1], [2], has been widely described. It is briefly described here and in Fig. 5 to point out one of its important features, and because an understanding of it is important in understanding the ac-dc ratiometer.

In Fig. 5, a dc-voltage $E_1$ is applied through a switch (usually a FET) for a prescribed time $t_1$. The integrator output reaches a voltage $E_1 t_1/RC$. Then $E_1$ is disconnected, and $E_2$ (which is of opposite polarity) is applied until the output again reaches zero as determined by the comparator. During this time period $t_2$ the output voltage has changed by $E_2 t_2/RC$. Thus since the final voltage is zero

$$\frac{E_1 t_1}{RC} = \frac{E_2 t_2}{RC} \quad \text{or} \quad \frac{E_1}{E_2} = \frac{t_2}{t_1}$$

and $t_2$ is a measure of the voltage ratio.

Note that the measured voltage ratio is independent of the value of the capacitor, which only has to remain unchanged for the time of the measurement. The capacitor can be chosen only for its value and low dielectric absorption. Usually a polystyrene, polycarbonate, or, in very precise devices, ®Teflon type is used.

One modification of the dual-slope integrator [3] is to apply the numerator $E_1$ for the whole measurement interval and to apply $E_2$ (with second resistor) in pulses of known duration whenever the output reaches a threshold level. Thus if the measurement period is $t_m$ and the pulse duration is $t_p$

$$\frac{E_1 t_m}{R_1 C} = \frac{E_2 N t_p}{R_2 C} + \text{remainder}$$

where $N$ is the number of pulses applied.

If the measurement period is so long that the remainder may be ignored

$$\frac{E_1}{E_2} \cong \frac{N t_p}{t_m} \frac{R_1}{R_2}$$

and the count $N$ is a measure of the ratio. If the remainder is important, it could be measured and the appropriate correction made in the readout. The accuracy of this correction would affect only the less significant digits of the result. Note in this modification the ratio of $t_p/t_m$ must be precise.

## AC-DC Ratiometer

The present ratiometer uses another modification of the dual-slope integrator previously described. A train of $N_1$ pulses of fixed length $t_p$ is applied to the control of $S_1$ (the gate of the FET), as in Fig. 6. Then whenever the output reaches a threshold level, the next pulse in the train is applied to the control of $S_2$ also. (This signal is "clocked" to allow only full length pulses.) Thus if the number of pulses applied to $S_2$ is $N_2$

$$\frac{N_1 t_p E_n}{R_1 C} = \frac{N_2 t_p E_d}{R_2 C} + \text{remainder.}$$

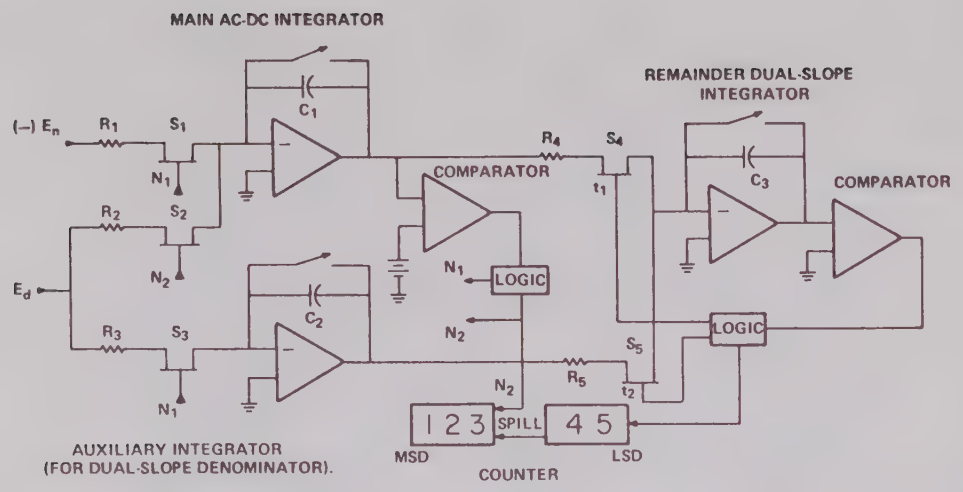



Fig. 8. AC–DC ratiometer. For ac operation pulses $N_1$ and $N_2$ rederived from signal having same frequency as $E_n$ and $E_d$.

As before, if $N_1$ is large enough, the remainder can be ignored and

$$\frac{E_n}{E_d} \cong \frac{N_2}{N_1}\frac{R_1}{R_2}.$$

The output voltage of the integrator presents interesting waveforms that depend upon the voltage ratio. Two simple ones are shown in Fig. 7. Note that the threshold voltage must be greater than the change in the output due to one pulse of $E_d$, $E_d t_p/R_2C$, if the remainder is always to be positive, and that the remainder can exceed this threshold value by this amount.

If the remainder cannot be ignored, it can be measured and used to correct the readout. One way to do this (Fig. 8) is to compare it against an integrated measure of $E_d$ with a dual-slope integrator and add it to the lesser digits of the readout. This measurement does depend upon a capacitance ratio $C_1/C_2$ but if $N_1 = 200$, a 1-percent change in this capacitance ratio would have only 0.01 percent on the reading (approximately).

So far we have been talking about dc-ratio measurements, but it is easy to see how this last scheme also works for ac if the gating pulses are square waves at the same frequency as the signals. The main integrator becomes an integrating phase-sensitive detector responding to those components of $E_n$ and $E_d$ that are inphase with the reference. The reference would be derived from zero crossings of $E_n$ or $E_d$ as required by the half-bridge circuits to obtain the series of parallel parameters. Otherwise, the operation is unchanged except that the ramps on the waveforms of Fig. 7 become partial sinusoidal curves.

Not only can both signals be ac or dc, one may be ac and the other dc. In this case, the ratio is that of the average value of the ac voltage to the dc voltage.

## Concluding Remarks

A *CRL* meter based on the half-bridge and ratiometer previously described has been developed to measure dc resistance and series inductance and capacitance at 1 kHz and 120 Hz. The dc measurements use a 1-kHz signal to derive the gating pulses. For both dc and 1-kHz measurements, there are 200 pulses in the pulse train ($N_1 = 200$) giving a measurement time of 200 ms plus a short settling time and a short time for the remainder dual-slope integrator. The full-scale reading is 19 999, and the specified accuracy of the instrument is expected to be 0.1 percent plus two counts (the ratiometer itself is substantially better). Only twenty pulses are used at 120 Hz to keep the measurement time short. The full-scale reading is 1999 and the accuracy is 0.25 percent plus one count. This test frequency is intended for electrolytic capacitors and iron-cored chokes, which rarely have tight tolerances.

The preceding specifications are comparable to those of currently available ac automatic bridges, but with the added dc resistance capability. It would seem that it would be difficult to meet and hold these specifications using the techniques currently used in impedance meters.

## References

[1] R. W. Gibert, "Pulse time encoding apparatus," U.S. Patent 3 074 057.
[2] H. Schmid, *Electronic Analog/Digital Conversions.* New York: Van Nostrand-Reinhold, 1970, p. 282.
[3] —, *Electronic Analog/Digital Conversions.* New York: Van Nostrand-Reinhold, 1970, p. 292.

Reprinted from *IEEE Transactions on Instrumentation and Measurement*, Vol. IM-22, No. 4, December, 1973.
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# Service and Maintenance—Section 5


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### 5.1 GR FIELD SERVICE.

The warranty attests the quality of materials and workmanship in our products. When difficulties do occur, our service engineers will assist in any way possible. If the difficulty cannot be eliminated by use of the following service instructions, please write or phone our Service Department (see last page of manual), giving full information of the trouble and of steps taken to remedy it. Be sure to mention the serial, ID, and type numbers of the instrument.

### 5.2 INSTRUMENT RETURN.

Before returning an instrument to General Radio for service, please contact our Service Department or nearest District Office requesting a "Returned Material" number. Use of this number will ensure proper handling and identification. For instruments not covered by the warranty, a purchase order should be forwarded to avoid unnecessary delay.

### 5.3 REPAIR OF PLUG-IN BOARDS.

This instruction manual contains sufficient information to allow the repair of faulty circuit boards by an experienced, skillful electronic technician. If for any reason the boards cannot be repaired, the instrument or boards can be returned to GR for repair.

For prompt replacement of etched-circuit logic, display and comparator board(s), a replacement can be ordered, and the faulty board returned after receipt of the replacement. Contact your nearest General Radio Repair Facility (see last page), supplying them the type, serial number and identification number of the instrument; the board part number (refer to the parts list for the number; the number etched on the foil-only-solid-side is *not* the part number) and letter designation (if any); and a purchase order number. The P.O. number allows for billing if the unit is out of warranty and/or for identification of the shipment. The repair facility will arrange for the prompt delivery of a replacement.

To prevent damage to the board, return the defective board in the packing, or equivalent packing, supplied with the replacement. Please identify the return with the Return Material number on the tag supplied with the replacement and ship to the address indicated on the tag.

### 5.4 MINIMUM-PERFORMANCE STANDARDS.

#### 5.4.1 General.

The following paragraphs contain information to determine that the 1685 is performing within specifications. The procedures enable instrument-standards laboratories and equivalently equipped service facilities to perform checks at periodic intervals and after repair, to determine that the instrument is operating properly. These procedures are bench checks that require the use of front-panel controls and externally available test points (i.e., instrument disassembly is neither required or recommended).

The following checks are included, to determine that the instrument is operating properly:

1. Dc Resistance
2. Capacitance
3. Inductance
4. Dissipation Factor.

NOTE

Allow 10 minutes warm-up time before performing check and calibration procedures.

Table 5-1 lists the test equipment required or recommended to perform the system minimum-performance checks, calibration procedures, and troubleshooting. Only the component standards, decade resistance boxes, and decade capacitance box are required for the minimum performance checks. Troubleshooting should only require a DVM, oscilloscope and possibly a frequency counter. All of the equipment listed in Table 5-1 is required for a complete unit check and calibration, however.

Make the following parameter checks using the standards called out in Table 5-2, where applicable. For the checks in paragraphs 5.4.2 thru 5.4.5, use the 1685-9291 test cable to connect directly to the standards. Refer to Section 2 for details on connections. Allow 3 minutes warm-up before making checks.

NOTE

Check the mid-scale value on each range listed in the following tables. Para 5.9.12 contains a check for the comparator unit, if installed.

**Table 5-1**
TEST EQUIPMENT

| Instrument | Requirement | Recommended* |
|---|---|---|
| Digital voltmeter | 0.1% accuracy or better | HP 3439A/3442A |
| Oscilloscope | 50 mV/cm sensitivity, 10 MHz bandwidth, | Tektronix 547 |
| Oscilloscope plug-in | See above | Tektronix 1A1 |
| Frequency counter | Range 100-Hz — 10-kHz frequencies; sensitivity 10 mV rms, impedance 100 kΩ; 5-digit readout | GR Type 1192 Counter |
| Precision resistors | .01 Ω<br>0.1 Ω<br>1 Ω<br>10 Ω | GR 1440-9671<br>GR 1440-9681<br>GR 1440-9601<br>GR 1440-9611 |
| Decade resistance box | Accuracy ±.01%, except 1 Ω, which is 0.1%. Known zero resistance and calibration data on the 1-k, 10-k, 100-k, 1-M, and 10-MΩ positions | GR 1433-9733 Decade Resistance Box |
| Resistors, 1 each | 100 Ω ±10%<br>500 Ω ±10%<br>910 Ω ±10%<br>1 kΩ ±10%,<br>3.3 kΩ ±10% | Decade resistance box may be used. Refer to Table 1-5 for suggested boxes. |
| Precision capacitors | 100 pF<br>1000 pF<br>0.1 μF<br><br>10 μF, known to be 0.1% or better<br>100 μF, known to be 1.0% or better<br>1 mF, known to be 0.25% or better<br>10 mF, known to be 0.25% or better | GR 1404-9702 (1404-B)<br>GR 1404-9701 (1404-A)<br>GR 1409-9720 (1409-T)<br>See Table 1-5 for details.<br>See Table 1-5 for suggested precision decade capacitors available from GR. |
| Capacitors, 1 each | 30 pF ±5%<br>70 pF ±5% | |
| Standard inductors | 10 μH, known to be 0.1%<br>100 μH<br>1 mH<br>10 mH<br>100 mH<br>1 H<br>10 H<br>100 H, known to 0.25%<br>(1 mH to 10 H, ±0.1% accuracy nominal inductance; 100 μH, accuracy ±0.25%. | <br>GR 1482-9702<br>GR 1482-9705<br>GR 1482-9708<br>GR 1482-9712<br>GR 1482-9716<br>GR 1482-9720 |
| Power Supply | 0-30 V dc, General purpose power supply. | HP 6215-A |

*Or equivalent.

### 5.4.2 DC Resistance Check

Make the checks listed in the table below. Do not fail to take into account the accuracy of standards used to perform the checks.

### 5.4.3 Capacitance Check

Make the checks listed in Table 5-3 below. Do not fail to take into account the accuracy of the standards used to perform the checks.

### 5.4.4 Inductance Check

Make the checks listed in Table 5-4 below. Do not fail to take into account the accuracy of the standards used in the checks.

**Table 5-2**
RESISTANCE CHECK

| Nominal R (Ω) | Range | Low Limit | High Limit | Accuracy (±%) |
|---|---|---|---|---|
| 0.1 | 2 | 099.1 m | 100.9 m | 0.9 |
| 1 | 3 | 0.997 | 1.003 | 0.3 |
| 10 | 3 | 9.988 | 10.012 | 0.12 |
| 100 | 4 | 99.88 | 100.12 | 0.12 |
| 1 k | 5 | 998.8 | 1001.2 | 0.12 |
| 10 k | 6 | 9.988 k | 10.012 k | 0.12 |
| 100 k | 7 | 99.88 k | 100.12 k | 0.12 |
| 1 M | 8 | 997.6 k | 1002.4 k | 0.24 |
| 10 M | 9 | 9.940 M | 10.060 M | 0.60 |

**Table 5-3**
CAPACITANCE CHECK

| Frequency (Hz) | C Standard | Range | Low Limit | High Limit | Accuracy (±%) |
|---|---|---|---|---|---|
| 120 | 10 mF | 1 | 09.86 mF | 10.14 mF | 1.4 |
| 120 | 1 mF | 2 | 0.992 mF | 1.008 mF | 0.75 |
| 1 k | 100 μF | 2 | 99.65 μF | 100.35 μF | 0.35 |
| 120 | 100 μF | 3 | 099.6 μF | 100.4 μF | 0.35 |
| 1 k | 10 μF | 3 | 9.988 μF | 10.012 μF | 0.12 |
| 120 | 10 μF | 4 | 09.96 μF | 10.04 μF | 0.35 |
| 1 k | 1 μF | 4 | 998.8 nF | 1001.2 nF | 0.12 |
| 120 | 1 μF | 5 | 0.996 μF | 1.004 μF | 0.35 |
| 1 k | 100 nF | 5 | 99.88 nF | 100.12 nF | 0.12 |
| 120 | 100 nF | 6 | 099.6 nF | 100.4 nF | 0.35 |
| 1 k | 10 nF | 6 | 9.988 nF | 10.012 nF | 0.12 |
| 120 | 10 nF | 7 | 09.96 nF | 10.04 nF | 0.35 |
| 1 k | 1 nF | 7 | 997.6 pF | 1002.4 pF | 0.24 |
| 120 | 1 nF | 8 | 0.993 nF | 1.007 nF | 0.70 |
| 1 k | 100 pF | 8 | 99.65 pF | 100.35 pF | 0.35 |

**Table 5-4**
INDUCTANCE CHECK

| Frequency (Hz) | L Standard | Range | Low Limit | High Limit | Accuracy (±%) |
|---|---|---|---|---|---|
| 120 | 10 μH | 1 | 009.9 μH | 010.1 μH | 0.9 |
| 1 k | 100 μH | 2 | 99.64 μH | 100.36 μH | 0.36 |
| 120 | 1 mH | 2 | 0.993 mH | 1.007 mH | 0.70 |
| 1 k | 1 mH | 3 | 998.8 μH | 1001.2 μH | 0.12 |
| 120 | 10 mH | 3 | 09.97 mH | 10.03 mH | 0.30 |
| 1 k | 10 mH | 4 | 9.988 mH | 10.012 mH | 0.12 |
| 120 | 100 mH | 4 | 099.7 mH | 100.3 mH | 0.30 |
| 1 k | 100 mH | 5 | 99.88 mH | 100.12 mH | 0.12 |
| 120 | 1 H | 5 | 0.996 H | 1.004 H | 0.35 |
| 1 k | 1 H | 6 | 998.8 mH | 1001.2 mH | 0.12 |
| 120 | 10 H | 6 | 09.96 H | 10.04 H | 0.35 |
| 1 k | 10 H | 7 | 9.988 H | 10.012 H | 0.12 |
| 120 | 100 H | 7 | 099.6 H | 100.4 H | 0.35 |
| 1 k | 100 H | 8 | 99.64 H | 100.36 H | 0.36 |

### 5.4.5 Dissipation Factor Check

Make the checks listed in Table 5-5 below. Do not fail to take into account the accuracy of the standards used in the checks.

## 5.5 PARTS LOCATIONS AND TEST POINTS.

Most of the parts and internal adjustments are on the etched-circuit boards. Figures 5-1 and 5-2 identify the parts. Test points are on the circuit boards; the test points are shown on the schematic diagrams and they are identified on the circuit boards by the designation TP.

Other points for monitoring signals are at wire-ties, identified on the schematics and circuit boards by the designation WT. The legend on the schematic denotes if the wire-tie called out on the schematic is located on the associated circuit board or on another board or chassis component. Wire-ties on chassis components are not identified in all cases. Use the schematic diagram to locate these ties.

Filter capacitors for the transformer assembly are located beneath the power supply board, on the left-hand side of the instrument.

The etched-board layouts in Section 6 identify the locations of all board adjustments.

## 5.6 REMOVAL-REPLACEMENT PROCEDURES.

### 5.6.1 Chassis.

Turn off the power before removing or installing any parts.

WARNING

**When the instrument is energized, there are high voltages present at the power switch, transformer, and transformer and bridge assembly at the rear of the power supply board, under the power supply's protective cover. High voltages are also present at the terminals of filter capacitors C501, C503 and C504, located beneath the power supply board.**

Refer to paragraph 2.3.1 or reverse the procedure in para 2.3.4.

CAUTION

Make sure no foreign matter, especially metal, falls on the bridge or logic boards when the chassis is out of the cabinet. This may short-circuit board signal lines. When swung open, be careful not to short-circuit the logic board test points on the left-hand side to the chassis directly or via a test probe.

### 5.6.2 Logic Board.

To remove the logic board, remove the 4 screws from periphery of the board (2 on the right-hand side and one each at the front and rear of the board).

The left-hand side of the board is mounted on hinges. Push the board back slightly to the rear and then swing the right-hand side out from the instrument.

Remove the 2 screws from the rear underside of the board and unplug the board from the connector socket.

### 5.6.3 Indicator Lamps.

If a front-panel lamp has to be replaced, carefully remove the lamp clip and remove the lamp. Replace the lamp(s) with a Chicago Miniature type CM377 or General Electric type 377 miniature lamp. Replace the lamp clip.

To gain access to the limit-comparator indicator lamps, carefully turn the instrument on its side. Replace the lamps as described above.

To replace the test fixture lamps, remove the lock nut from the lamp cap and replace the lamp with a Chicago Miniature type CM-328 or GE type 328 miniature lamp.

### 5.6.4 LED Readout Display

The LED display can be checked by means of the lamp-test (LT) input at the rear-panel MEASUREMENT DATA connector. A ground applied to the pin (refer to para 2.5)

Table 5-5

DISSIPATION FACTOR CHECK

| Frequency (Hz) | Range | Nominal C (μF) | Nominal Series R (Ω) | Nominal "D" | Low Limit | High Limit |
|---|---|---|---|---|---|---|
| 1 k | 5 | 0.1592 | 10 k | 10 | 4.5 | 15.5 |
| 1 k | 5 | 0.1592 | 1 k | 1 | 0.9 | 1.1 |
| 1 k | 5 | 0.1592 | 100 | 0.1 | .093 | 0.107 |
| 1 k | 5 | 0.1592 | 10 | .01 | .008 | .012 |
| 120* | 6 | 0.1327* | 100 k | 10 | 4.5 | 15.5 |
| 120 | 6 | 0.1327 | 10 k | 1 | 0.9 | 1.1 |
| 120 | 6 | 0.1327 | 1 k | 0.1 | .093 | 0.107 |
| 120 | 6 | 0.1327 | 100 | 0.01 | .008 | .012 |

*0.1592 μF for 100 Hz.

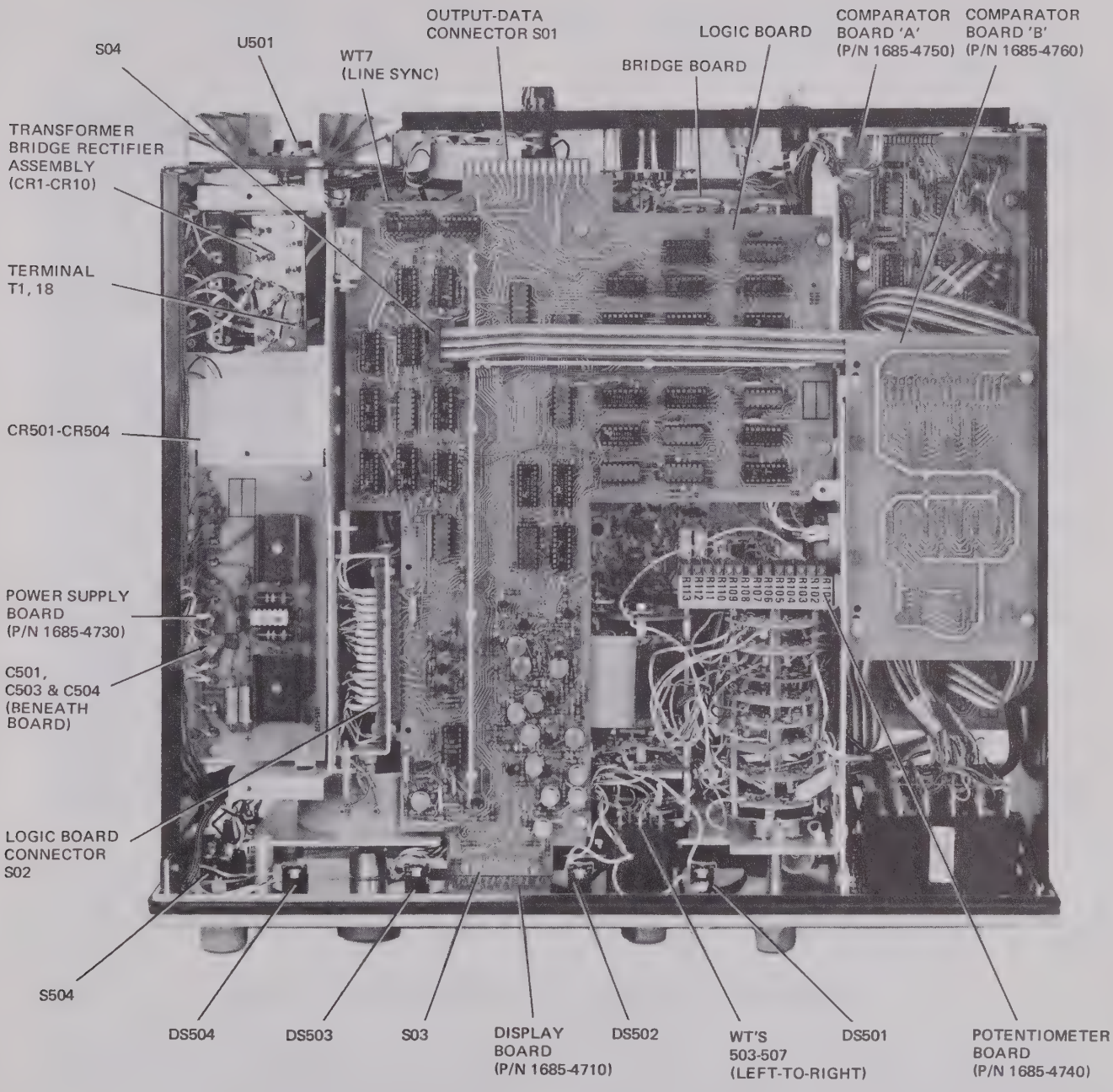


**Figure 5-1. Top view of meter with case removed and logic board secured in place.**

### 5.4.5 Dissipation Factor Check

Make the checks listed in Table 5-5 below. Do not fail to take into account the accuracy of the standards used in the checks.

## 5.5 PARTS LOCATIONS AND TEST POINTS.

Most of the parts and internal adjustments are on the etched-circuit boards. Figures 5-1 and 5-2 identify the parts. Test points are on the circuit boards; the test points are shown on the schematic diagrams and they are identified on the circuit boards by the designation TP.

Other points for monitoring signals are at wire-ties, identified on the schematics and circuit boards by the designation WT. The legend on the schematic denotes if the wire-tie called out on the schematic is located on the associated circuit board or on another board or chassis component. Wire-ties on chassis components are not identified in all cases. Use the schematic diagram to locate these ties.

Filter capacitors for the transformer assembly are located beneath the power supply board, on the left-hand side of the instrument.

The etched-board layouts in Section 6 identify the locations of all board adjustments.

## 5.6 REMOVAL-REPLACEMENT PROCEDURES.

### 5.6.1 Chassis.

Turn off the power before removing or installing any parts.

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Refer to paragraph 2.3.1 or reverse the procedure in para 2.3.4.

CAUTION

Make sure no foreign matter, especially metal, falls on the bridge or logic boards when the chassis is out of the cabinet. This may short-circuit board signal lines. When swung open, be careful not to short-circuit the logic board test points on the left-hand side to the chassis directly or via a test probe.

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To remove the logic board, remove the 4 screws from periphery of the board (2 on the right-hand side and one each at the front and rear of the board).

The left-hand side of the board is mounted on hinges. Push the board back slightly to the rear and then swing the right-hand side out from the instrument.

Remove the 2 screws from the rear underside of the board and unplug the board from the connector socket.

### 5.6.3 Indicator Lamps.

If a front-panel lamp has to be replaced, carefully remove the lamp clip and remove the lamp. Replace the lamp(s) with a Chicago Miniature type CM377 or General Electric type 377 miniature lamp. Replace the lamp clip.

To gain access to the limit-comparator indicator lamps, carefully turn the instrument on its side. Replace the lamps as described above.

To replace the test fixture lamps, remove the lock nut from the lamp cap and replace the lamp with a Chicago Miniature type CM-328 or GE type 328 miniature lamp.

### 5.6.4 LED Readout Display

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| 1 k | 5 | 0.1592 | 1 k | 1 | 0.9 | 1.1 |
| 1 k | 5 | 0.1592 | 100 | 0.1 | .093 | 0.107 |
| 1 k | 5 | 0.1592 | 10 | .01 | .008 | .012 |
| 120* | 6 | 0.1327* | 100 k | 10 | 4.5 | 15.5 |
| 120 | 6 | 0.1327 | 10 k | 1 | 0.9 | 1.1 |
| 120 | 6 | 0.1327 | 1 k | 0.1 | .093 | 0.107 |
| 120 | 6 | 0.1327 | 100 | 0.01 | .008 | .012 |

*0.1592 $\mu$F for 100 Hz.

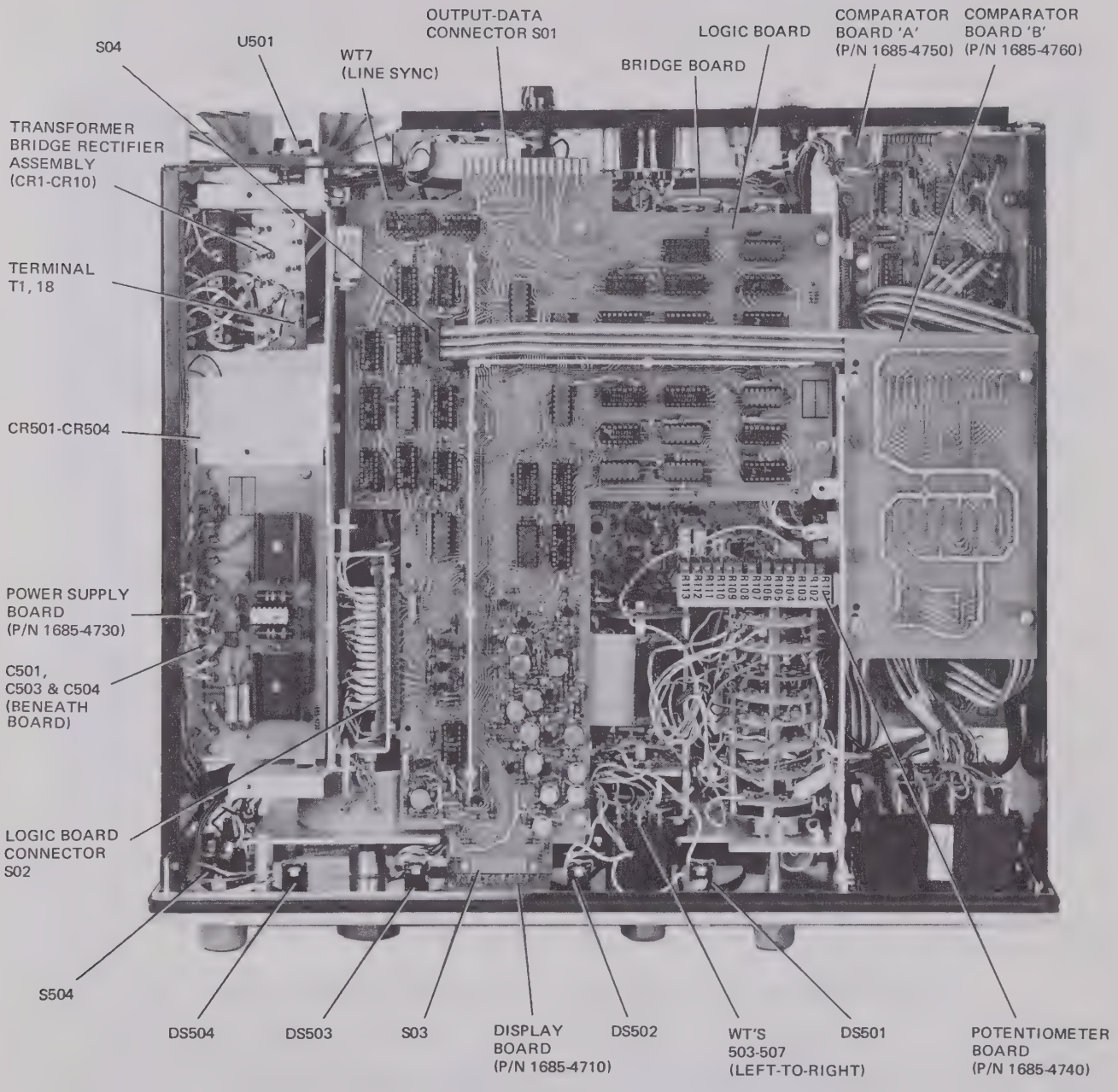


**Figure 5-1. Top view of meter with case removed and logic board secured in place.**

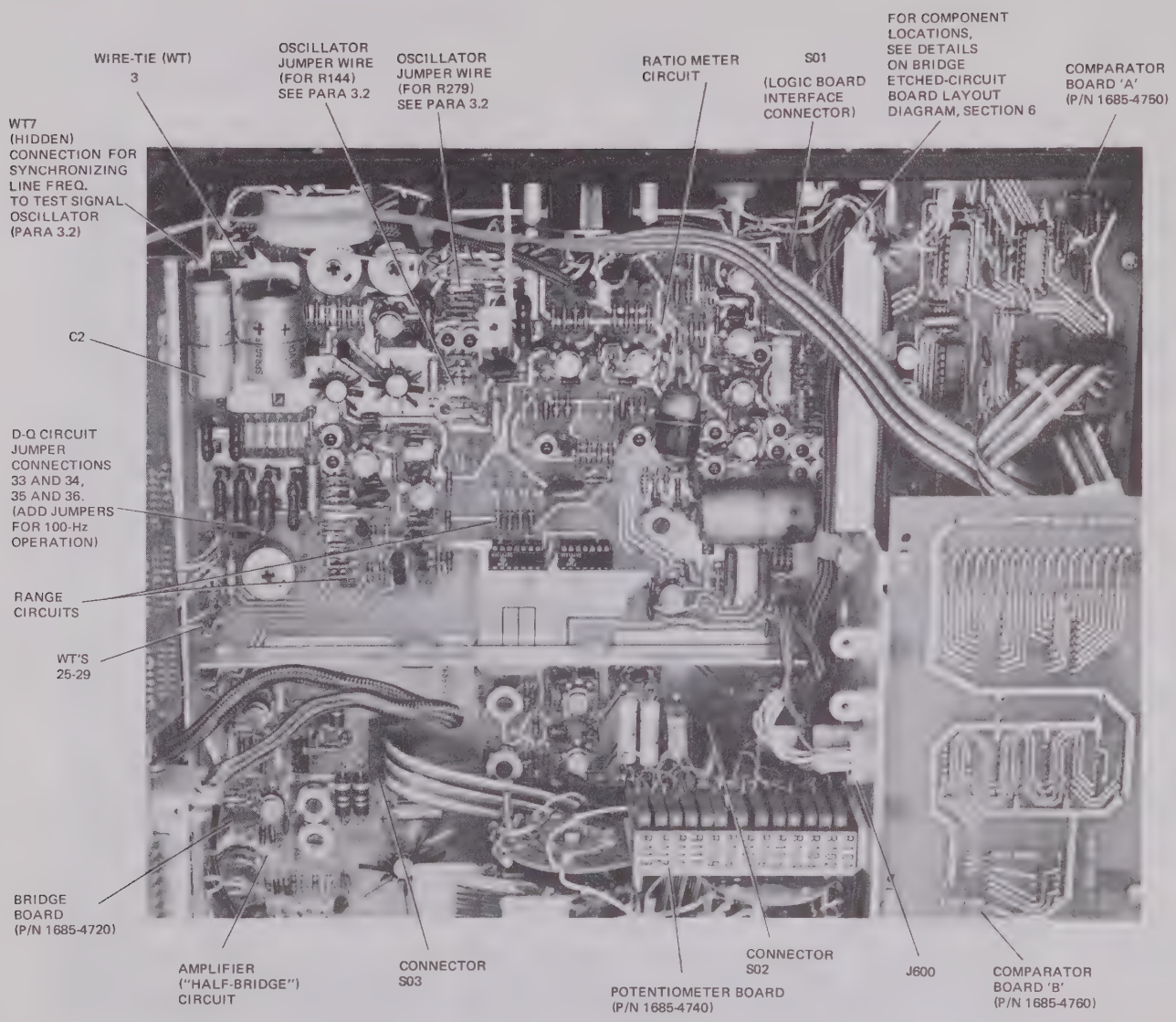
WIRE-TIE (WT) 3
OSCILLATOR JUMPER WIRE (FOR R144) SEE PARA 3.2
OSCILLATOR JUMPER WIRE (FOR R279) SEE PARA 3.2
RATIO METER CIRCUIT
S01 (LOGIC BOARD INTERFACE CONNECTOR)
FOR COMPONENT LOCATIONS, SEE DETAILS ON BRIDGE ETCHED-CIRCUIT BOARD LAYOUT DIAGRAM, SECTION 6
COMPARATOR BOARD 'A' (P/N 1685-4750)
WT7 (HIDDEN) CONNECTION FOR SYNCHRONIZING LINE FREQ. TO TEST SIGNAL OSCILLATOR (PARA 3.2)
C2
D-Q CIRCUIT JUMPER CONNECTIONS 33 AND 34, 35 AND 36. (ADD JUMPERS FOR 100-Hz OPERATION)
RANGE CIRCUITS
WT'S 25-29
BRIDGE BOARD (P/N 1685-4720)
AMPLIFIER ("HALF-BRIDGE") CIRCUIT
CONNECTOR S03
POTENTIOMETER BOARD (P/N 1685-4740)
CONNECTOR S02
J600
COMPARATOR BOARD 'B' (P/N 1685-4760)

**Figure 5-2. Top view of meter with case removed and logic swung open to show bridge board parts.**

will light all of the lamp segments, causing the display to read 8888. The most-significant digit (the "tens-of-thousands" digit 1) will not be lit, however.

If a lamp requires replacement, the display board can be removed from the logic board by removing the two screws from the front of the board. The board can either be replaced or the defective LED can be removed from the board and replaced with a new lamp.

If replacing the lamp, the lamp must be unsoldered from the board and the replacement must be soldered in its place. Take care not to damage the board or lamp when doing this; make sure that none of the tracks on the board are damaged or short-circuited when removing and replacing the lamp.

Replace the lamp with a Fairchild type FND 357 digital indicator.* If replacing the board, follow the instructions given in para 5.3.

If the light-emitting diode mounted below the display requires replacement, carefully unsolder the faulty diode and replace it with a Fairchild type FLV102 red light-emitting diode, or equivalent.

*Some instruments have type FND 70 indicators. Check the number on the part for the proper replacement.

### 5.6.5 Limit Comparator.

To remove any parts of the limit comparator, observe how the parts are secured by retaining screws. Disconnect the cables from the circuit boards. Figure 6-3 identifies the dual in-line connectors. Then remove the retaining screws and carefully remove the boards. Do not force the boards to remove them. The front-panel (switch assembly) also removes from the instrument. Cables are permanently fastened to the switch assembly. Remove the retaining screws and remove the assembly and associated cables.

### 5.6.6 Power Supply.

To gain access to the power supply and its components, remove the 3 screws from the protective cover on the left-hand side of the instrument; remove the cover. Power supply parts can be removed by unfastening the screws that secure the parts.

### 5.6.7 Switch Removal-Replacement.

To remove knobs:

a. Set the controls full ccw.

b. Hold the instrument securely and pull the knob off with fingers.

CAUTION

Do not use a screwdriver or other instrument to pry off the knob if it is tight, since this might mar the panel. Do not lose the retention spring in the knob when the knob is removed.

c. Remove the setscrew from the bushing; use a hex-socket key wrench.

d. Remove the bushing.

NOTE

If the knob and bushing are combined when the knob is removed, turn a machine tap a turn or two into the bushing on the dial for sufficient grip for easy separation of the knob.

e. If the switch is to be removed, remove the dress nut exposed after step d. (Also refer to instructions at the end of this paragraph, to gain access to the switches inside the instrument.)

Install the switches by reversing the removal procedure and performing the following steps:

a. Make sure the control shafts are turned full ccw.

b. Install the dress nut, if applicable.

c. Install the bushing on the shaft; tighten the setscrew.

NOTE

If the retention spring in the knob comes loose, reinstall it in the interior notch with the thin flange set into the small slit in the wall of the knob.

### 5.6.8 Other Parts

To gain access to various front-panel switches or parts of the switches, it may be necessary to loosen the bridge board at the bottom of the instrument. This will allow the board to be moved over to obtain space to work on the switches.

To do this, unplug the two ribbon cable assemblies from sockets S02 and S03 on the bridge board. These are the ribbon cables connected to the switches. (Refer to Figure 5-2 for the locations.) Then carefully turn the instrument on its side and remove the 8 screws from the bottom of the bridge board. Only remove those screws that hold the board on the chassis brackets. It is not necessary to remove all the screws on the circuit board. This will allow the board to be moved a few inches away from the instrument, exposing the front-panel switches. *Do not pull* the board out too far, since the board is still connected to other cables that cannot be unplugged from the board.

## 5.7 REFERENCE DESIGNATIONS.

Refer to Section 6, if necessary, for a description of the reference designators used on drawings and the instrument.

## 5.8 PERIODIC MAINTENANCE.

Keep the instrument cover, panels, controls and connectors clean and make sure connections to the instrument are clean. The limit-comparator digit-switches require special cleaning precautions. To prevent damage to the plastic parts used on the digit-switch assembly, it is recommended that a solution of 40% isopropyl alcohol and 60% distilled water be used to clean the face of the switch. Freon TF can also be used. Wipe the switch face lightly using a Q-Tip, Kimwipe or soft cloth moistened in the cleaner approved for this application. If the alcohol and water mixture is used for cleaning, wipe the switch face dry immediately with a dry wiper. Do not blow the switch face dry or allow the cleaner to run inside the switch.

To remove solder flux near Lexan plastic, isopropyl alcohol (99%) is recommended. Apply the solvent to the terminal area with a brush or Q-Tip. Allow the solvent to act for 30 to 60 seconds, using brushing action as required. Wipe the solvent and flux off with a clean Q-Tip or Kimwipe. Repeat if necessary. Do not use excess solvent, and hold the assembly with the printed circuit boards oriented so the solvent will flow away from the switch.

## 5.9 CHECKS AND ADJUSTMENTS.

### 5.9.1 General.

Refer to para 5.6 for details as how to remove the assembly from the instrument case and how to gain access to the instrument's circuit boards.

NOTE

Allow at least 10 minutes warm-up time before performing any checks and calibrations. Perform the "Minimum-Performance Checks" first to determine if complete recalibration is required. Check and recalibrate only those areas that appear to be out of tolerance from the measurements made in the "Minimum-Performance Checks."

### 5.9.2 Power Supply Check.

With a DVM, check the following DC voltages on the 1685-4730 power supply board.

DVM Low (WT6), High (WT7) — +5V DC ±0.25V

DVM Low (WT9), High (WT8) — +15V DC ±0.5V

DVM Low (WT9), High (WT10) — −15V DC ±0.5V

Note the three power supply voltages should not vary more than ±10mV from 90 to 127 V AC input voltage. Reset the line-voltage switch to 115V AC input voltage.

With an oscilloscope, check the power supply noise on the 1685-4730 power supply board.

Scope Low (WT6), High (WT7) — noise <200 mV-pk-pk

Scope Low (WT9), High (WT8) — noise <30 mV pk-pk

Scope Low (WT9), High (WT10) — noise <30 mV pk-pk

### 5.9.3 Oscillator Checks and Calibration.

Make the following oscillator checks and adjustments if necessary:

a. Connect the + current (+I) and + potential (+P) leads together at the end of the 1685-0291 measurement cable, and then connect the — current and — potential leads together.

b. Connect an oscilloscope and a frequency counter to the plus (+) current lead (high) and its shield (Low) or to terminals WT2 (Low) WT3 (High) on the 1685-4720 bridge board.

c. Set the PARAMETER switch (S502) to C-1 kHz, and MEASUREMENT MODE switch to REPETITIVE.

d. Observe 1 kHz ±1 Hz on the counter. Also observe a clean sine wave on the scope; if not, adjust R25 for 1 kHz ±1 Hz on the counter.

e. Short-circuit WT7 on the 1685-4720 bridge board to chassis ground (120-Hz sync).

f. Set the PARAMETER switch to C-120 Hz; note a clean sine wave on the scope and measure 120 Hz ±2 Hz on the counter.

g. Remove the short circuit from WT7. The counter should indicate 120 Hz ±0.2 Hz. This is with the 120-Hz sync added.

h. Connect the DVM (high) to S502 (PARAMETER switch) terminal 109 F (top-front of first waffer); connect low to chassis ground.

i. Set the PARAMETER switch to C-1 kHz and measure and adjust R18 if necessary, for a reading of 5.0 V ±.05 V rms.

j. Set the PARAMETER switch to C-120 Hz. The DVM should indicate 5V ±0.05 V rms. Set the PARAMETER switch to R-DC; the DVM should read 10 V DC ±0.4 V.

k. Connect the DVM to +I+P (high) and -I-P (low) leads and check the following ranges. Set the PARAMETER switch to R-DC:

| Meter Range | DC Voltage (V) |
|---|---|
| 9 | +10.7 to +9.3 |
| 8 | +10.7 to +9.3 |
| 7 | +2.2 to +1.8 |
| 6 | +2.2 to +1.8 |
| 5 | +2.2 to +1.8 |
| 4 | +2.2 to +1.8 |
| 3 | +2.2 to +1.8 |
| 2 | +0.25 to +0.20 |
| 1 | +0.25 to +0.20 |

l. Disconnect the DVM.

### 5.9.4 DC Calibration and Range Accuracy Check.

*Internal Zero.* Make the following checks and adjustments if necessary.

a. Connect a decade resistance box to the 1685-0291 cable, connected to the 1685, in a 4-terminal connection as shown in Figure 5-3.

b. Set the 1685 RANGE switch to 8 and PARAMETER switch to R—DC.

c c. Set the decade box to 43 Ω.

d. Observe and adjust R128 so that the 1685 display indicates 000.0 when the decade box is set to 43 Ω, and 000.1 when the decade box is set to 57 Ω. Repeat this adjustment to account for any interaction between the settings.

e. Set the 1685 RANGE switch to 1, and the PARAMETER switch to R-DC.

f. Connect the .01-Ω standard to the 1685 via a 4-terminal connection.

g. Observe and adjust R47, if necessary, so that the 1685 display indicates between 09.98 and 10.02 mΩ.

h. Set the 1685 RANGE switch to range 6.

i. Connect the decade box set to 100 Ω to the 1685 via a 4-terminal connection.

NOTE

Account for decade box zero resistance.

j. Observe and adjust R106 for a reading of 0.100, and center the adjustment; that is, turn R106 in one direction to 0.101 then back to 0.100, then to 0.099. Count the turns and set the potentiometer to the center position.

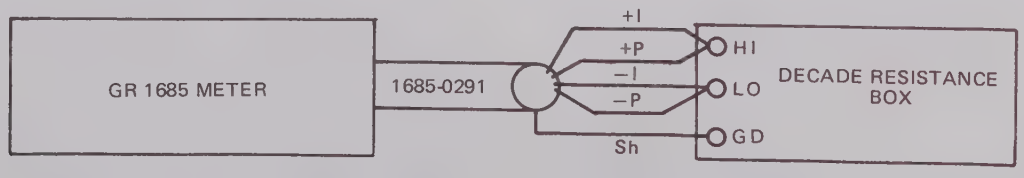


**Figure 5-3. Dc calibration and range accuracy test setup.**

k. Set the decade box to 10.000 kΩ. Add a 910-Ω resistor from +I+P to ground. Observe and adjust R60 for the same reading on the 1685, 10.000 with and without the 910-Ω resistor. Remove the 910-Ω resistor.

l. Set the decade box to 100 Ω. Add a 1-kΩ resistor in series with the -I lead. Observe and adjust R-262 if necessary for the same reading on the 1685, 0.100 kΩ with and without the 1-kΩ resistor.

*Range Linearity.* Make the following checks and adjustments as necessary.

a. Set the decade box to 10.000 kΩ.

b. Connect the decade box via a 4-terminal connection to the 1685.

c. Observe and adjust R103 for a reading on the 1685 equal to the calibrated value of the decade box 10.000-kΩ position. Repeat steps a thru e in the previous procedure ("Internal zero") if the reading is greater than ±10 counts of the value.

d. Set the decade box to 20.000 kΩ; the 1685 should read 19.995 kΩ to 20.005 kΩ.

e. Set the decade box to 2.000 kΩ; the 1685 should read 2.000 kΩ, within ±2 counts.

f. If the above checks of steps d and e are not within limits, repeat the procedure, starting at step a. "Internal zero" (para 5.11.4). There is some interaction between potentiometers.

g. Set the 1685 RANGE switch to 9. Set decade box to 10.00 MΩ. Observe and adjust R59 if necessary for a reading on the 1685 equal to the calibrated value of the 10.00-MΩ position. If the reading is greater than ±10 counts of the value, repeat the procedure, starting at step a, under "Internal zero."

h. Set the 1685 RANGE switch to 8. Set decade box to 1.000 MΩ; check that 1685 indicates between 999.3 and 1000.7. Attenuate (pad) R279, if required. Repeat steps g and h if the padding is used.

i. Set the decade box and 1685 controls to the following positions and observe the 1685 reading noted.

| Decade | 1685 Range | High Limit | Low Limit | Notes |
|---|---|---|---|---|
| 10.000 MΩ | 9 | 10.000 | 10.000 | Adjust R59. |
| 1.0000 MΩ | 8 | 1001.5 | 998.5 | —pad R279 if necessary |
| 100.00 kΩ | 7 | 100.10 | 99.90 | |
| 10.000 kΩ | 6 | 10.010 | 9.980 | |
| 1.0000 kΩ | 5 | 1001.0 | 999.0 | |
| *100.0 Ω | 4 | 100.10 | 99.90 | |
| *10.0 Ω | 3 | 10.010 | 9.990 | |
| *1.0 Ω | 2 | 1001.0 mΩ | 999.0 mΩ | —pad R271 if necessary |
| *0.1 Ω | 1 | 100.80 mΩ | 99.20 mΩ | |

*Subtract the decade box zero setting resistance value (13-15 mΩ nominal, on 1433/34) from 1685 readings in the range below 100 Ω, or use the GR 1440 standard resistors.

### 5.9.5 AC Adjustment C-1 kHz.

To check and adjust the AC test frequency:

a. Set 1685 RANGE switch to 4 and set the PARAMETER switch to C-1 kHz.

b. Connect the 1685 as shown in Figure 5-4.

c. Observe and adjust R85 if necessary so that the 1685 C display indicates 000.0 with the 30-pF capacitor connected and 000.1 with the 70-pF capacitor connected. (R191 may have to be adjusted to set R85 correctly.)

d. Set 1685 RANGE switch to 5 and PARAMETER switch to C-1 kHz.

e. Connect the 1685 as shown in Figure 5-5.

f. Add a 1-kΩ resistor in series with the +I lead. Set the decade "C" box to 0.1 μF. Observe and adjust R92 so that the 1685 indicates the same value (0.10 μF) with and without the 1-kΩ resistor. Remove the resistor.

g. Add a 500-Ω resistor in series with the —I lead and check that the C values measured with and without the 500-Ω resistor do not differ by more than 0.2% (20 counts). Remove the 500-Ω resistor.

h. Add a 3.3-kΩ resistor in series with the high side of the decade box (or 1409) and the junction of the —I—P leads.

i. For the low D check, observe and adjust R105 if necessary so that the 1685 indicates the calibrated value of the 1409-T 0.1-μF standard, with no resistor in series with the —I—P leads and the high terminal of the 1409.

j. For the high D check, observe and adjust R110 if necessary so that the 1685 indicates the calibrated value (±7 counts) of the 1409-T 0.1 μF standard, with the resistor in series with the —I—P leads and the low terminal of the 1409. R105 and R110 interact; repeat steps i and j until the readings are the same. Remove the 1409 and the 3.3-kΩ resistor.

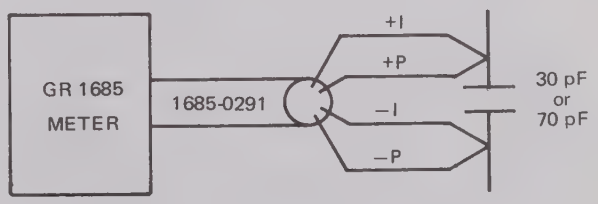


**Figure 5-4. Ac adjustment test setup, range 4.**

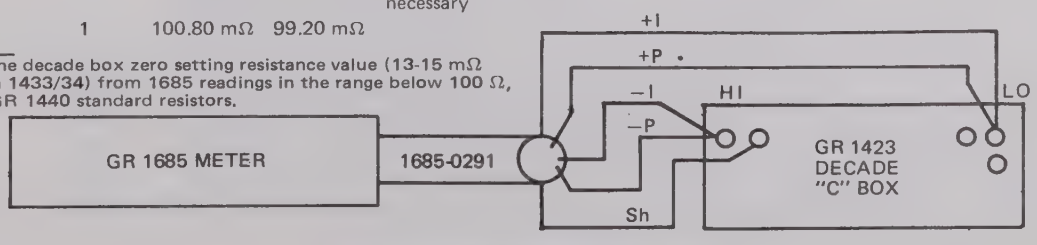


**Figure 5-5. Ac adjustment test setup, range 5.**

### 5.9.6 AC Adjustment C-120 Hz.

To check and adjust the 120-Hz frequency:

a. Set 1685 RANGE switch to 6 and PARAMETER switch to C-120 Hz.

b. Connect the 1685 as shown in Figure 5-4.

c. Check that the 1685 indicates 000.0 with a 30-pF capacitor connected and 000.1 with the 70-pF capacitor connected.

d. Set the 1685 RANGE switch to 5 and the PARAMETER switch to C-120 Hz.

e. Connect the 100-nF capacitor as shown in Figure 5-5, without any resistor. Observe and adjust R107 if necessary so that the 1685 indicates 100.0 nF. Determine the point where the reading is obtained then center the adjustment to prevent fluctuations.

f. Change the 1685 RANGE to 6.

g. Observe and adjust R104 if necessary so that the 1685 indicates the calibrated value of the 1409-T 0.1-$\mu$F standard or the 0.1-$\mu$F step of the GR 1423 decade box.

h. Add a 27-k$\Omega$ resistor in series with the high side of the GR 1409 or GR 1423 and the junction of the –I–P leads; the 1685 C display should indicate between 099.8 and 100.2 mF, and D $\approx$ 2. If the above readings are not within limits, repeat the procedure, starting at step a.

### 5.9.7 D-Q 1-kHz Check and Adjustment.

To check and adjust D-Q at a 1-kHz frequency:

a. Set the 1685 RANGE switch to 6 and PARAMETER switch to C-1 kHz.

b. Connect the 1685 as shown in Figure 5-6.

c. Set the 1423 for .0159 $\mu$F and set the 1433 for 10 $\Omega$.

d. Observe and adjust R113 if necessary for a D reading of .001 (to the point where the D dial left- and right-hand lights blink).

e. Change 1433 to 50 $\Omega$.

f. Check for a D reading of .005 on 1685 D dial; if not correct, repeat the procedure, starting at step c. (There are two positions of R113 for a D of .001.)

g. Set the 1433 for 20 k$\Omega$ and adjust R236 if necessary for a D reading of 2.

h. Set the 1433 to 100 $\Omega$ and measure and record the D dial reading.

i. Change the 1685 RANGE switch to position 4 and adjust R191 if necessary for same D reading as in step h.

j. Repeat steps c thru i. These adjustments interact.

k. Check the D dial to see if it is within the limits listed below. Set the 1433 to the indicated value for each reading.

| GR 1433 Setting | D Nominal | Low Limit | High Limit |
|---|---|---|---|
| 10 $\Omega$ | .001 | .000 | .002 |
| 50 $\Omega$ | .005 | .00375 | .00625 |
| 100 $\Omega$ | .01 | .0085 | .0115 |
| 200 $\Omega$ | .02 | .018 | .022 |
| 500 $\Omega$ | .05 | .046 | .054 |
| 1 k$\Omega$ | 0.1 | .093 | 0.107 |
| 2 k$\Omega$ | 0.2 | 0.187 | 0.213 |
| 5 k$\Omega$ | 0.5 | 0.46 | 0.54 |
| 10 k$\Omega$ | 1 | 0.90 | 1.1 |
| 20 k$\Omega$ | 2 | 1.7 | 2.3 |
| 100 k$\Omega$ | 10 | 4.5 | 15.5 |

### 5.9.8 D-Q 120-Hz Check and Adjustment.*

To check and adjust D-Q at a 120-Hz frequency, use the same setup shown in Figure 5-6 and perform the following steps:

a. Set the 1423 to 0.1327 $\mu$F* and set the 1685 RANGE switch to 6 and the PARAMETER switch to C-120 Hz.

b. Set the 1433 to 10 $\Omega$ and adjust R112 if necessary for a D reading of .001. (Set the D dial to 0.001 and adjust R112 for a balance as indicated by the green and red D-Q lamps.)

c. Check the D dial to see if it is within the limits listed below. Set the 1433 to the indicated value for each reading.

| 1433 Setting | D Nominal | Low Limit | High Limit |
|---|---|---|---|
| 10 $\Omega$ | .001 | .000 | .002 |
| 50 $\Omega$ | .005 | .00375 | .00625 |
| 100 $\Omega$ | .01 | .0085 | .0115 |
| 200 $\Omega$ | .02 | .018 | .022 |
| 500 $\Omega$ | .05 | .046 | .054 |
| 1 k$\Omega$ | 0.1 | .093 | 0.107 |
| 2 k$\Omega$ | 0.2 | 0.187 | 0.213 |
| 5 k$\Omega$ | 0.5 | 0.46 | 0.54 |
| 10 k$\Omega$ | 1 | 0.90 | 1.1 |
| 20 k$\Omega$ | 2 | 1.7 | 2.3 |
| 100 k$\Omega$ | 10 | 4.5 | 15.5 |

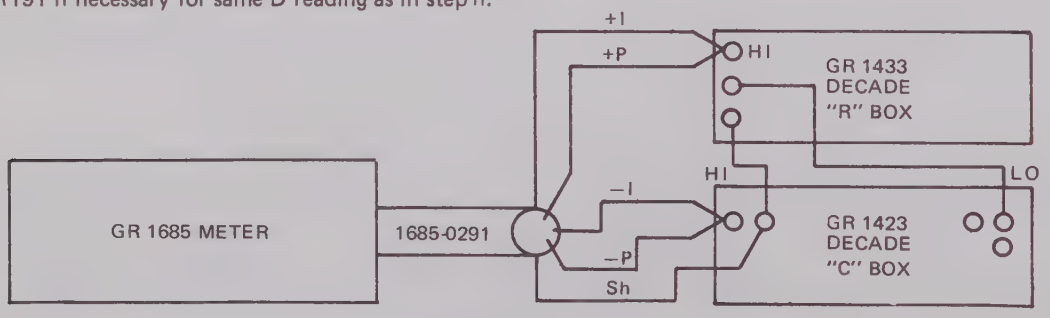


**Figure 5-6. D-Q 1-kHz test setup.**

*Use 0.1592 $\mu$F for 100-Hz instruments.

**5.9.9 Inductance 1-kHz Check and Calibration.**

To check and adjust inductance at a 1-kHz test frequency:

a. Set the 1685 RANGE switch to 5 and PARAMETER switch to L-1-kHz.

b. Connect a high Q 100-mH inductor (1481, 1490 or 1491 Decade Inductor) to the 1685 as shown in Figure 5-7.

c. Add a 1.3-kΩ resistor in series with the junction of the —I—P leads and the low side of the inductor decade. Observe and adjust R111 if necessary so that the 1685 L readout is the same with and without the 1.3-kΩ series resistor.

d. Connect the 1685 to a 100-mH low-Q standard (GR 1482, for example).

e. Observe and adjust R101 if necessary so that the 1685 L readout is the calibrated value of the 100-mH standard. Recheck the adjustment, since R111 and R101 interact.

f. Adjust R108 if necessary for a "Q" dial reading of 145 (if using a 1481, 1490 or 1491 set to 100-mH) or the calibrated "Q" value of the high-Q 100-mH standard.

g. Add a small resistor (2 Ω) in series with the high-Q inductor. Check for a Q dial reading of 100. If incorrect, repeat the above adjustment of R108, since there are two settings for R108.

**5.9.10 Inductance 120-Hz Check and Calibration.**

To check and adjust inductance at a 120-Hz test frequency, set the 1685 RANGE switch to 4 and PARAMETER switch to L-120 Hz and perform the following steps:

a. Connect the 100-mH high-Q inductor to the 1685, with 150 Ω in series with the —I—P leads as shown in Figure 5-7; the 1685 should indicate the same L value (±0.3 mH) with and without the resistor.

b. Remove the resistor and connect a GR 1482 100-mH low-Q standard inductor to the 1685.

c. Observe and adjust R102 if necessary so that the 1685 L readout indicates the calibrated 120-Hz value of the 1482 100-mH standard.

d. Reconnect the 100-mH high-Q inductor.

e. Observe and adjust R109 so that the 1685 Q dial indicates the Q value of the high-Q inductor (1481, 1490, 1491 = 20-22).

f. Add a small resistor, 4 Ω, in series with the high-Q inductor. The Q dial reading should be 10; if not, repeat Step e, since there are two settings for R109.

**5.9.11 Capacitor Checks with Internal and External Bias.**

a. Connect the 1685-P1 Test Fixture to the meter and set the CAPACITOR BIAS switch to the INTERNAL 2 V position.

b. Check the voltage on the 1685-P1 to see if it is between 1.88V and 2.12V. With a DVM, check for correct polarity on the 1685-P1.

c. Connect a HP-6215A power supply to the EXTERNAL BIAS jacks at rear panel. Set the CAPACITOR BIAS switch to the EXTERNAL position and the power supply to its zero volts out setting.

d. Check the voltage on the 1685-P1 while increasing the power supply voltage to 30 VDC. Check the polarity at the 1685-P1. Observe the warning given in para. 3.4 for external bias connections.

**5.9.12 Comparator Check.**

If the 1685 is equipped with the Data Output option, check the data output lines while checking the limit comparator. Refer to Figure 2-4 for the data output connector pin numbers.

a. Connect a GR 1433-N Decade Resistor (0.1 Ω — 10 kΩ) to the meter and set the 1685 RANGE switch to 5, PARAMETER switch to R DC, and MEASUREMENT MODE switch to REPETITIVE, 0.5 s.

b. For a Low-Limit check, set the comparator, HIGH LIMIT to 19999, and the LOW LIMIT switches to 00000.

c. Set the 1433 to 0000.0 Ω; the 1685 should read 0000.0 Ω and the GO lamp should light. Check that the comparator operates according to Table 5-6 for 0.1-Ω steps. At each step check the 1685 reading to see that it is the same as the 1433 setting ±0.1% + 1 count.

d. Repeat above procedure for 1.0-Ω, 10.0-Ω, 100.0-Ω steps.

e. Check the comparator according to Table 5-7 for 1-kΩ steps.

f. For the High Limit check, set the comparator HIGH LIMIT switches to 00000 and LOW LIMIT switches to 00000.

g. Set 1433 to 0000.0 Ω, and set the 1685 RANGE switch to 5, the PARAMETER switch to R DC, and the MEASUREMENT MODE switch to REPETITIVE 0.5 s. The 1685 should read 0000.0 Ω and the GO lamp should light. Check that the comparator operates according to Table 5-8 for 0.1-Ω steps. At each step check the read-

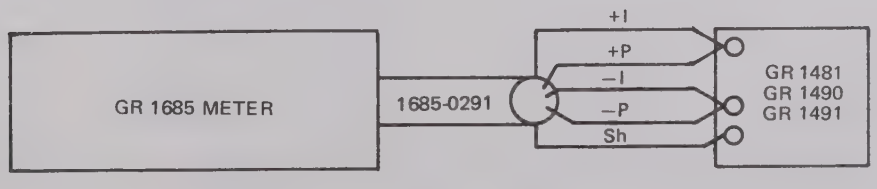


**Figure 5-7. Inductance test setup.**

ing of the 1685 to see if it is the same as the 1433 setting ±0.1% + 1 count.

h. Repeat above procedure for 1.0 Ω, 10.0 Ω, 100.0 Ω steps, but leave the comparator least-significant-digit reading a 9.

For example, for 10.0 Ω

| | GR 1685 | GR 1433 | HIGH Lamp |
|---|---|---|---|
| Test first reading is | 00009 | 000.0 Ω | —— |
| Second reading | 00109 | 0010.0 Ω | ON |

Check the comparator according to Table 5-9 for 1-kΩ steps, then disconnect the 1433.

i. To check the comparator High D function, set the 1685 and comparator controls as follows. Use the setup described in para 5.9.7 but set the 1433 to a 1-kΩ setting):

| | |
|---|---|
| HIGH LIMIT | 16000 |
| LOW LIMIT | 00000 |
| RANGE | 6 |
| PARAMETER | C-1 kHz |

j. Rotate the D-Q dial through its range and note that whenever the dial is below the actual D reading (approx. 0.1), the comparator HIGH D light lights and whenever the D-Q dial indicates above the actual D reading, the GO light lights.

**Table 5-6**
COMPARATOR LOW-LIMIT CHECK

| 1685 Low Limit Switch | GR 1433 | GO Lamp | LOW Lamp |
|---|---|---|---|
| 00000 | 0000.0 Ω | ON | — |
| 00001 | 0000.0 Ω | — | ON |
| 00001 | 0000.1 Ω | ON | — |
| 00002 | 0000.1 Ω | — | ON |
| 00002 | 0000.2 Ω | ON | — |
| 00003 | 0000.2 Ω | — | ON |
| 00003 | 0000.3 Ω | ON | — |
| 00004 | 0000.3 Ω | — | ON |
| 00004 | 0000.4 Ω | ON | — |
| 00005 | 0000.4 Ω | — | ON |
| 00005 | 0000.5 Ω | ON | — |
| 00006 | 0000.5 Ω | — | ON |
| 00006 | 0000.6 Ω | ON | — |
| 00007 | 0000.6 Ω | — | ON |
| 00007 | 0000.7 Ω | ON | — |
| 00008 | 0000.7 Ω | — | ON |
| 00008 | 0000.8 Ω | ON | — |
| 00009 | 0000.8 Ω | — | ON |
| 00009 | 0000.9 Ω | ON | — |
| 00000 | 0000.9 Ω | ON | — |
| 00000 | 0000.0 Ω | ON | — |

**Table 5-8**
COMPARATOR HIGH-LIMIT CHECK

| 1685 High Limit Switch | GR 1433 | GO Lamp | HIGH Lamp |
|---|---|---|---|
| 00000 | 0000.0 Ω | ON | — |
| 00000 | 0000.1 Ω | — | ON |
| 00001 | 0000.1 Ω | ON | — |
| 00001 | 0000.2 Ω | — | ON |
| 00002 | 0000.2 Ω | ON | — |
| 00002 | 0000.3 Ω | — | ON |
| 00003 | 0000.3 Ω | ON | — |
| 00003 | 0000.4 Ω | — | ON |
| 00004 | 0000.4 Ω | ON | — |
| 00004 | 0000.5 Ω | — | ON |
| 00005 | 0000.5 Ω | ON | — |
| 00005 | 0000.6 Ω | — | ON |
| 00006 | 9999.6 Ω | ON | — |
| 00006 | 0000.7 Ω | — | ON |
| 00007 | 0000.7 Ω | ON | — |
| 00007 | 0000.8 Ω | — | ON |
| 00008 | 0000.8 Ω | ON | — |
| 00008 | 0000.9 Ω | — | ON |
| 00009 | 0000.9 Ω | ON | — |
| 00009 | 0000.0 Ω | ON | — |

**Table 5-7**
COMPARATOR LOW-LIMIT 1-kHz CHECK

| 1685 Low Limit Switch | GR 1433 | GO Lamp | LOW Lamp | HIGH Lamp |
|---|---|---|---|---|
| 00000 | 0000.0 Ω | ON | — | — |
| **10000 | 0000.0 Ω | — | ON | — |
| **00000 | 0000.0 Ω | ON | — | — |
| 10000 | 2000.0 Ω | — | | ON* |
| 00000 | 0000.0 Ω | ON | — | — |

*The 1685 must show ERROR (E)
**Repeat at least five times to check each position of switch (5 zero's, 5 one's). Rotate left wheel of 1685 LOW or HIGH LIMIT switch (as applicable) through its 10 positions.

**Table 5-9**
COMPARATOR HIGH LIMIT 1-kΩ CHECK

| 1685 High Limit Switch | GR 1433 | GO Lamp | HIGH Lamp |
|---|---|---|---|
| 09999 | 0000.0 Ω | ON | — |
| **09999 | 1000.0 Ω | — | ON |
| **19999 | 1000.0 Ω | ON | — |
| 19999 | 2000.0 Ω | — | ON* |
| 00000 | 0000.0 Ω | ON | — |

Table 5-10

TROUBLE ANALYSIS

| Fault | Probable Cause | Remedy |
|---|---|---|
| Instrument fails to operate in any mode of operation. | Defective power supply, bridge-board oscillator; logic board BST-pulse circuitry, oscillators, or readout circuitry.<br>NOTE<br>If fault appears to be one that affects timing or overall performance of instrument, it is suggested that logic board be checked using timing diagram, Figure 6-9, and logic board schematic, Figure 6-10. Also check that the oscillator is operating. (Signal REF will be present.) If it appears that the fault is related to instrument accuracy (slightly inaccurate readings, for example) check the bridge board using the check and calibration procedures in para 5.9. | Perform lamp test to see if readout display is working. If display is not operating, check for power supply or readout circuit failure. Check at rear-panel MEASUREMENT DATA connector to see if measurement data is present. If it is, it will help isolate fault between logic board counters and drivers and readout meter and its associated logic-board circuits. Check power supply output (para 5-11) and/or voltages on logic board. Check oscillator output, if necessary, at C2 on the bridge board. If present, check the inputs and outputs of the logic board (timing diagram, Fig. 6-12), particularly signals HF, DNC, CP1 (may not always be present) and CP2. Check at both circuit boards, If present, check logic board counters and associated latches and multiplexers. Also check signal SDL on logic board, which is used to strobe data out of latches. Refer to the diagram (Fig. 6-4) showing the bridge-board signal waveforms for each PARAMETER mode of operation, to isolate faults to the bridge-board circuitry. |
| Instrument operates for only certain parameters and/or only certain ranges. | No oscillator output for selected parameter, bridge section faulty, range circuitry faulty. | Check the oscillator output at C2 (WT3) on the bridge board (or signal REF on the logic board). Refer to the bridge configuration diagrams in Section 4 and Figure 6-4 showing the bridge-board signal waveforms for each parameter. From these and the parameter that is faulty, check the appropriate bridge arm(s) and parameter switch circuitry to see if signals are present. If not, check the components and connections. Also check measurements on various ranges to help isolate faults to the range circuitry on the RANGE switch. If a range is defective, refer to the bridge board schematic diagram and RANGE switch layout diagram to identify and locate components. |
| Measurements slightly inaccurate | Bridge-board or oscillator out of adjustment or has failed part. | Refer to paragraphs 5-4 and 5-9; use the procedure for the specific measurement parameter that is malfunctioning. |
| Limit Comparator not operating properly, but meter operates properly. | Comparator boards and assemblies and/or interface signals. Cable connections. | After ensuring that all connections are secured (Figure 6-3), use the timing diagram on the comparator 'A' board (Figure 6-12) and the logic board schematic and system timing diagram (Figure 6-9) to check the signals on and between the comparator boards and instrument boards. Signals between the comparator and the instrument are via connector S04 on the logic board. Use the theory of operation, if necessary, to determine the required states of other signals on the comparator boards. Replace board(s) or faulty part. |
| Error reset time too slow | Q26 and associated circuitry | Short-circuit TP-6 to ground; if reset speeds up then Q26 may be leaking. |
| No down-count pulse at TP3 | CP2 pulse stuck low | Check and repair associated circuit. |
| No reset pulse in repetitive mode. | CP2 pulse stuck high | Check and repair associated circuit. |
| Only "hundreds" and above readout digits operable. | Display or logic board malfunction or CP2 stuck low. | Perform lamp test to check display. Check logic board circuitry, particularly inputs from the PARAMETER switch (signal $\overline{\text{A2LGC}}$ on board) and associated gates and flip-flops on board. Also check "count" oscillator and associated circuits. Check "units" and "tens" decade counters. |
| Only "units" and "tens" readout digits operable. | Bridge and logic board CP1 pulse circuitry; logic board F-F U26, gates U31 and/or counters. | Check circuitry listed under "probable cause." |

Table 5-10 (cont)
TROUBLE ANALYSIS

| Fault | Probable Cause | Remedy |
|---|---|---|
| Certain indicator lamps do not operate. | Lamp or signal circuitry. | Use the rear-panel connector or logic-board test points, where applicable, to determine if the circuitry or lamp is faulty. For example, the bridge and logic board contains a significant amount of circuitry for high-dissipation factor measurements. Signal HID can be monitored on the logic board or rear-panel MEASUREMENT-DATA connector. |

## 5.10 TROUBLE ANALYSIS.

Table 5-10 lists some faults that might occur in the instrument, the probable cause, and gives suggestions on how to isolate the fault. This information will help isolate a fault to a general area on circuit boards or assemblies. Integrated circuits are mounted in sockets for easy replacement of defective parts. Use the following aids to help isolate the fault to the part level.

1. Descriptions and simplified and equivalent drawings in Section 4.
2. Adjustment and calibration procedures in para 5-11, one for each measurement function.
3. Timing and schematic drawings in Section 6.
4. Waveforms and voltage levels on drawings in Section 6.
5. Test points on the circuit boards.
6. Parts list in Section 6.

For major types of faults where it appears that the instrument is not just out of calibration or adjustment (as indicated perhaps by slightly inaccurate readings as opposed to very inaccurate measurements), it is suggested that the following method be used to quickly check various parts of the instrument.

If a selection of various standards or components are available, make R, L, and C measurements to see if the instrument operates in any of these modes. If it operates in some modes but not others, it may indicate that the bridge section or RANGE or PARAMETER switches may not be operating properly but the oscillator and logic board circuits are functioning properly. (The check and calibration procedure in para 5.9 for the specific function and the bridge board waveform shown in Figure 6-4 can be used to isolate faults.)

The rear-panel data outputs can be checked to see if certain signals are present, indicating that the instrument's circuits are functioning. (For example, the RESET signal, data outputs, STROBE signal, etc.) The presence or absence of these signals will indicate a minor or major failure and help determine where a fault may lie. Remote-start the instrument to see if it functions in this manner.

If no improvements are noted, check the oscillator output (para 5-9). Then, if necessary, check the oscillator output (para 5.9) and logic circuit-board signals. Use the timing diagram (Figure 6-9) and the logic circuit-board schematic (Figure 6-10) to check the logic board.

Set the instrument in the REPETITIVE mode of operation and check all the signals to and from the logic board, as shown in Figure 6-9. Test points are furnished at all board inputs and outputs.

If signal REF is missing, check the oscillator output. Signal REF is derived from the oscillator and is routed via the bridge board to the logic board, where it it used to initiate most of the timing functions on the board and in the instrument.

The oscillator can be checked by connecting an oscilloscope to capacitor C2 on the bridge board. If the signal is present, isolation of the fault can be made by further examination of the bridge board, using the bridge-board schematic and the bridge-board waveforms shown in Figure 6-4.

All the test points on the logic board should be checked. If any signal is missing, examination of the schematic diagrams and the circuitry associated with the signal will help determine the location of the fault.

In most cases it will be possible to isolate faults between the bridge and logic boards and the comparator (if included in the instrument) in this manner.

If the instrument is making measurements but the differences in the measurement and actual component values are quite large, the fault may be in either the bridge or logic board, even if all the signals shown in Figure 6-9 are present. For example, the analog circuit could be faulty, putting out a slope signal (CP2) sooner or later than normal. Or it could fail to produce signal CP1, or perhaps produce too many CP1 signals (Although it should be noted that in some cases signal CP1 may not be produced, depending on the value of the part under test. In some cases a range change will produce the signal and verify its presence.) The logic board counting and associated circuits may be faulty, resulting in improper readings. This will require further troubleshooting of the board.

In any event, systematic checking such as described above will result in isolation of the malfunction. Use the equivalent diagrams in Section 4 to determine the bridge configurations for the various PARAMETER switch settings, if required. Read Section 4 to obtain a good understanding of how this complex instrument operates. Use this information to aid in troubleshooting.

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## 1.1 GENERAL

This section contains the parts lists, circuit-board layout diagrams and schematic and logic diagrams for the instrument. Section 4 contains functional diagrams of the various circuits shown in the schematic and logic diagrams. Section 5 contains photographs of the instrument, identifying various parts. The heavy lines on drawings denote the major signal flow in the circuits and instrument.

Reference designation usage is described in paragraph 6.2.

## 6.2 REFERENCE DESIGNATIONS

Each component on an assembly is identified on equipment and drawings by means of a reference designator comprised of numbers and letters. Component types on an assembly are numbered sequentially, the numbers being preceeded by a letter designation that identifies the component (R for resistor, C for capacitor, etc.). Each assembly (usually circuit boards and main frame) has its own sequence of parts designators.

Main-frame-mounted parts are identified by numbers having three digits, the first of which is the number 5 (C501, R508, CR506, for example).

The designation WT (wire-tie point) replaces the customary AT (anchor terminal) designation. The purpose of other references and symbols is given on the drawings in this section.

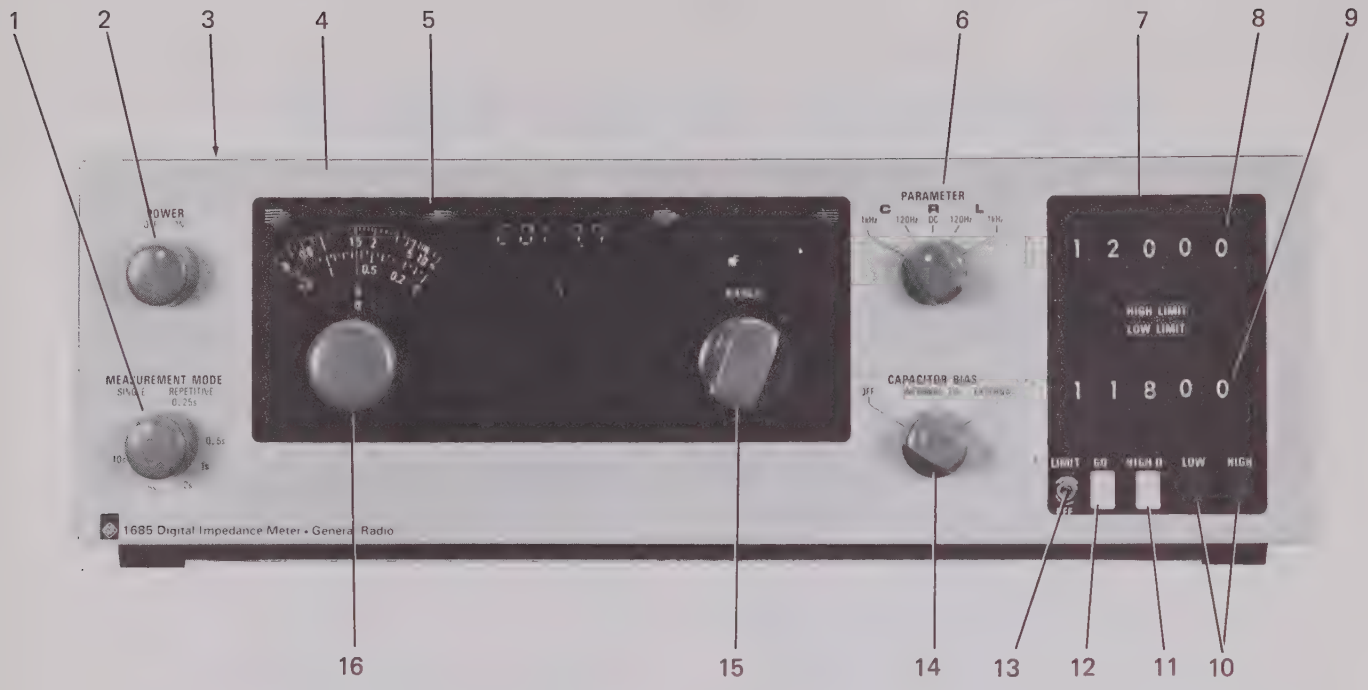



Figure 6-1. Front-panel view identifying parts.

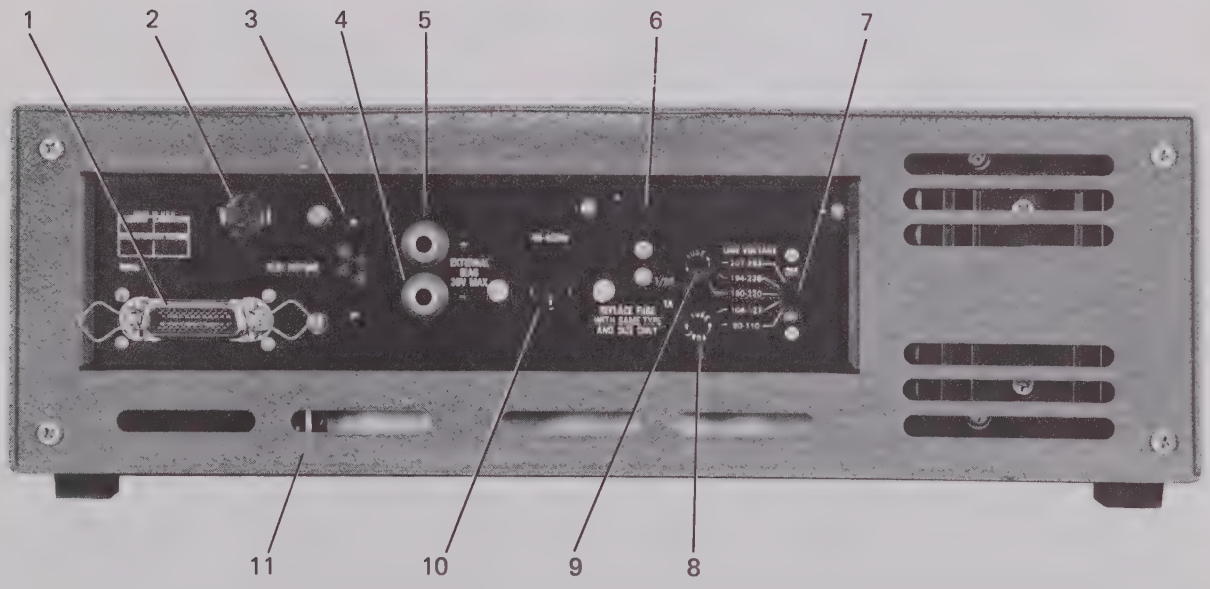



Figure 6-2. Rear-panel view identifying parts.

## MECHANICAL PARTS LIST

| Fig Ref | Qnt | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|---|
| | | FRONT PANEL | | | |
| 1 | 1 | Knob asm, MEASUREMENT MODE | 5520-5321 | 24655 | 5520-5321 |
| | | includes | | | |
| | 1 | Retainer | 5220-5402 | 24655 | 5220-5402 |
| 2 | 1 | Knob asm, POWER | 5520-5321 | 24655 | 5520-5321 |
| | | includes | | | |
| | 1 | Retainer | 5220-5402 | 24655 | 5220-5402 |
| 3 | 1 | Cabinet asm | 1685-2030 | 24655 | 1685-2030 |
| 4 | 1 | Gasket | 5331-3099 | 24655 | 5331-3099 |
| 5 | 1 | Window asm | 1685-7021 | 24655 | 1685-7021 |
| 6 | 1 | Knob asm, PARAMETER CRL | 5500-5321 | 24655 | 5500-5321 |
| | | includes | | | |
| | 1 | Retainer | 5220-5402 | 24655 | 5220-5402 |
| 7 | 1 | Switch bracket asm | 1685-2050 | 24655 | 1685-2050 |
| 8 | 1 | Switch, thumbwheel, 5-digit, HIGH LIMIT | 7917-1014 | 24655 | 7917-1014 |
| 9 | 1 | Switch, thumbwheel, 5-digit, LOW LIMIT | 7917-1014 | 24655 | 7917-1014 |
| 10 | 2 | Holder, lamp, LOW, HIGH | 5600-1032 | 24655 | 5600-1032 |
| 11 | 1 | Holder, lamp, HIGH D | 5600-1021 | 24655 | 5600-1021 |
| 12 | 1 | Holder, lamp, GO | 5600-1035 | 24655 | 5600-1035 |
| 13 | 1 | Switch, toggle, LIMIT OFF | 7910-0790 | 95146 | MTA-106D |
| 14 | 1 | Knob asm, CAPACITOR BIAS, | 5500-5321 | 24655 | 5500-5321 |
| | | includes | | | |
| | 1 | Retainer | 5220-5402 | 24655 | 5220-5402 |
| 15 | 1 | Knob asm, RANGE, | 5500-5421 | 24655 | 5500-5421 |
| | | includes | | | |
| | 1 | Retainer | 5220-5401 | 24655 | 5220-5401 |
| 16 | 1 | Knob asm, DQ | 5520-5420 | 24655 | 5520-5420 |
| | | includes | | | |
| | 1 | Retainer | 5220-5401 | 24655 | 5220-5401 |
| | | REAR PANEL | | | |
| 1 | 1 | Receptacle, 24 contacts | 4230-4024 | 02660 | 57-40240 |
| | | Part of 1685-4750 | | | |
| 2 | 1 | Receptacle, 5 contacts | 4230-5405 | 02660 | 126-218 |
| 3 | 1 | Hood, pin | 4230-0318 | 00779 | 201785-4 |
| | 1 | Recpt coax 7-cont male housing | 4230-0319 | 00779 | 50063-1 |
| | 1 | Jackscrew | 4230-0321 | 00779 | 200874-2 |
| | | TEST FIXTURE | | | |
| 4 | 1 | Banana jack, 100 | 4150-0900 | 24655 | 4150-0900 |
| | | EXTERNAL BIAS 100 MAX | | | |
| 5 | 1 | Banana jack, | 4150-0900 | 24655 | 4150-0900 |
| | | EXTERNAL BIAS 100V MAX + | | | |
| 6 | 1 | Plate, cover | 1685-8160 | 24655 | 1685-8160 |
| 7 | 1 | Switch, power line, LINE VOLTAGE | 7890-1082 | 24655 | 7890-1082 |
| | | OFF-ON | | | |
| 8 | 1 | Post, fuse-extractor, 1A | 5650-0100 | 71400 | HKP-H |
| 9 | 1 | Post, fuse-extractor, ½A | 5650-0100 | 71400 | HKP-H |
| 10 | 1 | Receptacle, power, 48-440 Hz | 4240-0210 | 24655 | 4240-0210 |
| 11 | 1 | Cover, cabinet rear | 1685-8210 | 24655 | 1685-8210 |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | MAIN INSTRUMENT ASSEMBLY PARTS | | | |
| | CAPACITORS | | | |
| C501 | Electrolytic, 22000 uF +75-10% 15 V | 4450-6509 | 56289 | 36D, 22000 uF +75-10% 15 V |
| C502 | Electrolytic, 2000 uF ±10% 6 V | 4450-6106 | 56289 | 30D, 2000 uF ±10% 6 V |
| C503 and | | | | |
| C504 | Electrolytic, 9700 uF +75-10% 30 V | 4450-6511 | 56289 | 36D, 9700 uF +75-10% 30 V |
| C505 | Tantalum, 1 uF ±20% 35 V | 4450-4300 | 56289 | 150D, 1 uF ±20% 35 V |
| C506 | Tantalum, 6.8 uF ±20% 6 V | 4450-4800 | 56289 | 150D, 6.8 uF ±20% 6 V |
| | DIODES | | | |
| CR501 thru | | | | |
| CR504 | | 6081-1032 | 24655 | 6081-1032 |
| | FUSES | | | |
| F1 | Slo-Blo, 1A | 5330-1400 | 71400 | MDL 1A |
| F2 | Slo-Blo, ½A | 5330-1000 | 71400 | MDL ½A |
| | INTEGRATED CIRCUITS | | | |
| U501 | Linear, Type LM323 | 5432-1048 | 12040 | LM323 |
| | JACKS | | | |
| J1 | Receptacle, power | 4240-0210 | 24655 | 4240-0210 |
| J4 | Receptacle, coax, 7-contact | 4230-0319 | 00779 | 50063-1 |
| J5 and | | | | |
| J6 | Jack, banana pin | 4150-0900 | 24655 | 4150-0900 |
| J7 | Receptacle, min 5-contact | 4230-5405 | 02660 | 126-218 |
| J502 | Connector, PC 15-positions | 4230-5230 | 02660 | 225-21521-401-117 |
| J503 | Connector, 21-contact | 4230-7100 | 24655 | 4230-7100 |
| J600 | Receptacle, min 5-contact | 4230-5405 | 02660 | 126-218 |
| | LAMPS | | | |
| DS501 thru | | | | |
| DS504 | 6.3 V | 5600-0319 | 71744 | CM-377 |
| WT503 thru | | | | |
| WT507 | 6.3 V | 5600-0319 | 71744 | CM-377 |
| | RESISTORS | | | |
| R500 | Pot., 1 megohm ±20% | 6045-5110 | 24655 | 6045-5110 |
| R501 | Potentiometer | 0975-4110 | 24655 | 0975-4110 |
| R502 | Comp., 1 megohm ±5% 1/4 W | 6099-5105 | 01121 | RCR07G105J |
| | SWITCHES | | | |
| S504 | Power | 7890-6510 | 24655 | 7890-6510 |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | SWITCH BRACKET ASSEMBLY PARTS | | | |
| Switch bracket Assembly Complete | | 1685-2050 | 24655 | 1685-2050 |
| | LAMPS | | | |
| DS1 thru | | | | |
| DS4 | 6.3 V | 5600-0319 | 71744 | CM-377 |
| | SWITCHES | | | |
| S1 thru | | | | |
| S5 | Thumbwheel | 7917-1014 | 24655 | 7917-1014 |
| S6 thru | | | | |
| S10 | Thumbwheel | 7917-1014 | 24655 | 7917-1014 |
| S11 | Toggle | 7910-0790 | 95146 | MTA-106D |

## ELECTRICAL PARTS LIST

BRIDGE BOARD (P/N 1685-4720) PARTS

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| CAPACITORS | | | | |
| C2 | Electrolytic, 125uF, +150-10% 100 V | 4450-6156 | 56289 | 43D, 125uF +150-10% 100 V |
| C3 | Electrolytic, 500 uF +150-10% 20 V | 4450-6020 | 56289 | 30D, 500 uF +150-10% 20 V |
| C4 thru C6 | Mica, 10000 uF ±1% 300 V | 4560-0300 | 14655 | CM-07, 10000 uF ±1% |
| C7 | Ceramic, .010uF ±20% 100 V | 4400-6534 | 72982 | 8131, .01 uF ±20% |
| C11 | Ceramic, 3300 pF ±10% 100 V | 4400-6525 | 72982 | 8131, 3300 pF ±10% |
| C12 | Ceramic, 330 pF ±10% 100 V | 4400-6441 | 72982 | 8101, 330 pF ±10% |
| C15 and C16 | Ceramic, 0.1 uF +80-20% 100 V | 4403-4100 | 72982 | 300-100-Z5V-104Z |
| C20 | Plastic, 1.0 uF ±5% 50 V (matched to 1%) | 1685-0400 | 24655 | 1685-0400 |
| C21 | Mica, 20000 uF ±1% 300 V | 4560-0400 | 14655 | CM-07, 20000 uF ±1% |
| C22 | Mica, 301 pF ±1% 500 V | 4710-0481 | 14655 | CM05, 301 pF ±1% |
| C23 | Plastic, 1.0 uF ±5% 50 V (matched to 1%) | 1685-0400 | 24655 | 1685-0400 |
| C24 | Mica, 0.02 uF | 0505-4413 | 24655 | 0505-4413 |
| C25 | Mica, 324 pF ±1% 500 V | 4710-0470 | 14655 | CM05, 324 pF ±1% |
| C30 | Mylar, 0.1 uF ±10% 100 V | 4860-8250 | 56289 | 410P, 0.1 uF ±10% 100 V |
| C32 | Mylar, 0.1 uF ±10% 100 V | 4860-8250 | 56289 | 410P, 0.1 uF ±10% 100 V |
| C35 thru C38 | Ceramic, 0.1 uF +80-20% 100 V | 4403-4100 | 72982 | 300-100-Z5V-104Z |
| C39 | Ceramic, 680 pF ±5% 100 V | 4400-6450 | 72982 | 8111, 680 pF ±5% |
| C40 | Poly., .05 uF ±0.5% 100 V | 4872-1202 | 24655 | 4872-1202 |
| C41 and C42 | Poly., 0.45 uF ±0.5% 100 V | 4872-1212 | 24655 | 4872-1212 |
| C43 and C44 | Ceramic, 0.47 uF ±20% 50 V | 4400-2054 | 72982 | 8131, 0.47 uF ±20% |
| C45 | Mylar, 0.1 uF ±10% 100 V | 4860-8250 | 56289 | 410P, 0.1 uF ±10% 100 V |
| C50 and C51 | Ceramic, 0.47 uF ±20% 50 V | 4400-2054 | 72982 | 8131, 0.47 uF ±20% |
| C54 | Mica, 2000 uF ±1% 500 V | 4710-2620 | 14655 | CM06, 2000 pF ±1% |
| C55 and C56 | Mica, .0012 uF ±1% 500 V | 4710-1210 | 14655 | CM06, 1200 pF ±1% |
| C57 and C58 | Mica, 10000 uF ±1% 300 V | 4560-0300 | 14655 | CM-07, 10000 uF ±1% |
| C59 | Mica, 2000 uF ±1% 500 V | 4710-2620 | 14655 | CM06, 2000 pF ±1% |
| C60 | Ceramic, 0.1 uF ±20% 50 V | 4400-2050 | 72982 | 8131, 0.1 uF ±20% |
| C61 | Tantalum, 4.7 uF ±20% 50 V | 4450-4990 | 56289 | 150D, 4.7 uF ±20% 50 V |
| C62 | Ceramic, 0.22 uF ±20% 50 V | 4400-2052 | 72982 | 8131, 0.22 uF ±20% |
| C63 | Ceramic, .010 uF ±20% 100 V | 4400-6534 | 72982 | 8131, .01 uF ±20% |
| C64 | Ceramic, .022 uF ±20% 100 V | 4400-6536 | 72982 | 8141, .022 uF ±20% |
| C65 | Tantalum, 33 uF ±20% 20 V | 4450-5613 | 56289 | 150D, 33 uF ±20% 20 V |
| C101 and C102 | Ceramic, 33 pF ±5% 100 V | 4400-6485 | 72982 | 8101, 33 pF ±5% |
| C103 | Ceramic, 4.7 pF ±5% 100 V | 4411-2005 | 72982 | 8101, 4.7 pF ±5% |
| C104 | Ceramic 15 pF ±5% 100 V | 4400-6481 | 72982 | 8101, 15 pF ±5% |
| C105 thru C111 | Ceramic, 33 pF ±5% 100 V | 4400-6485 | 72982 | 8101, 33 pF ±5% |
| C112 thru C131 | Ceramic, 0.1 uF ±20% 50 V | 4400-2050 | 72982 | 8131, 0.1 uF ±20% |
| C133 thru C143 | Ceramic, 0.1 uF ±20% 50 V | 4400-2050 | 72982 | 8131, 0.1 uF ±20% |
| C145 and C146 | Ceramic, .010 uF ±20% 100 V | 4400-6534 | 72982 | 8131, .01 uF ±20% |

## ELECTRICAL PARTS LIST

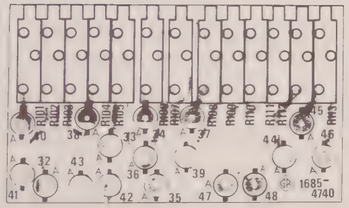
| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| CAPACITORS (cont) | | | | |
| C148 | Ceramic, 1000 pF ±10% 100 V | 4400-6519 | 72982 | 8121, 1000 pF ±10% |
| C149 | Ceramic, 1.0 uF ±20% 50 V | 4400-2070 | 72982 | 8131, 1 uF ±20% |
| C150 | Ceramic, 680 pF ±5% 100 V | 4400-6450 | 72982 | 8111, 680 pF ±5% |
| C151 | Ceramic, 1000 pF ±10% 100 V | 4400-6519 | 72982 | 8121, 1000 pF ±10% |
| C152 | Ceramic, 1.0 uF ±20% 50 V | 4400-2070 | 72982 | 8131, 1 uF ±20% |
| C153 | Ceramic, .010 uF ±20% 100 V | 4400-6534 | 72982 | 8131, .01 uF ±20% |
| C154 and C155 | Tantalum, 47 uF ±20% 20 V | 4450-5614 | 56289 | 150D, 47 uF ±20% 20 V |
| C156 | Ceramic, 4700 pF ±10% 50 V | 4400-6356 | 72982 | 8121, 4700 pF ±10% |
| C157 | Ceramic, 0.1 uF ±20% 50 V | 4400-2050 | 72982 | 8131, 0.1 uF ±20% |
| C158 | Ceramic, 270 pF ±10% 100 V | 4400-6514 | 72982 | 8101, 270 pF ±10% |
| C159 | Ceramic, .022 uF ±20% 100 V | 4400-6536 | 72982 | 8141, .022 uF ±20% |
| C160 and C161 | Ceramic, .010 uF ±20% 100 V | 4400-6534 | 72982 | 8131, .01 uF ±20% |
| C162 and C163 | Ceramic, 100 pF ±5% 100 V | 4400-6442 | 72982 | 8101, 100 pF ±5% |
| C164 | Ceramic, .022 uF ±20% 100 V | 4400-6536 | 72982 | 8141, .022 uF ±20% |
| C165 | Ceramic, 33 pF ±5% 100 V | 4400-6485 | 72982 | 8101, 33 pF ±5% |
| C166 and C167 | Ceramic, 0.1 uF ±20% 50 V | 4400-2050 | 72982 | 8131, 0.1 uF ±20% |
| C168 | Ceramic, 33 pF ±5% 100 V | 4400-6485 | 72982 | 8101, 33 pF ±5% |
| C169 | Ceramic, 2700 pF ±10% 100 V | 4400-6524 | 72982 | 8121, 2700 pF ±10% |
| C170 and C171 | Tantalum, 10 uF ±20% 20 V | 4450-5100 | 56289 | 150D, 10 uF ±20% 20 V |
| C173 | Ceramic, 0.68 uF ±20% 50 V | 4400-2058 | 72982 | 8131, 0.68 uF ±20% |
| DIODES | | | | |
| CR1 thru CR16 | Type 1N459A | 6082-1011 | 14433 | 1N459A |
| CR20 thru CR24 | Type 1N459A | 6082-1011 | 14433 | 1N459A |
| CR25 | Type 1N191 | 6082-1008 | 14433 | 1N191 |
| CR26 thru CR35 | Type 1N459A | 6082-1011 | 14433 | 1N459A |
| CR36 thru CR39 | Type 1N748A | 6083-1002 | 14433 | 1N748A |
| CR40 | Type IN957B | 6083-1009 | 14433 | IN957B |
| IC SOCKETS | | | | |
| S01 thru S03 | DIP, 14-contact, PC | 7540-1815 | 71785 | 133-51-02-003 |
| INTEGRATED CIRCUITS | | | | |
| U1 | Linear, Type LM301A | 5432-1004 | 12040 | LM301A |
| U2 thru U7 | Linear, Type LM308A | 5432-1027 | 12040 | LM308A |
| U8 | Linear, Type LM201A | 5432-1045 | 12040 | LM201A |
| U9 | Linear, Type LM301A | 5432-1004 | 12040 | LM301A |
| U10 and U11 | Linear, Type LM201A | 5432-1045 | 12040 | LM201A |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| INTEGRATED CIRCUITS (cont) | | | | |
| U12 and U13 | Linear, Type LM311 | 5432-1023 | 12040 | LM311 |
| U14 | Linear, Type LM301A | 5432-1004 | 12040 | LM301A |
| U15 | Linear, Type LM201A | 5432-1045 | 12040 | LM201A |
| U16 thru U19 | Linear, Type LM301A | 5432-1004 | 12040 | LM301A |
| U20 and U21 | Digital, Type SN74LS132N | 5431-8732 | 01295 | SN74LS132N |
| RESISTORS | | | | |
| R12 and R13 | Comp., 10 ohms ±5% 1/4 W | 6099-0105 | 01121 | RCR07G100J |
| R14 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R15 and R16 | Comp., 3 kilohms ±5% 1/4 W | 6099-2305 | 01121 | RCR07G302J |
| R17 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R18 | Pot,Wire-wound, 1 kilohm ±1% | 6056-0138 | 11236 | Series 115, Type 115, 1 kilohm ±10% |
| R19 | Thermistor, 100 kilohms ±20% | 6740-2021 | 83186 | 51A16/GR |
| R20 | Comp., 1.5 kilohms ±5% 1/4 W | 6099-2155 | 01121 | RCR07G152J |
| R21 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R22 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R23 | Film, 15.8 kilohms ±1% 1/8 W | 6250-2158 | 75042 | CEA, 15.8 kilohms ±1% |
| R24 | Film, 15 kilohms ±1% 1/8 W | 6250-2150 | 75042 | CEA, 15 kilohms ±1% |
| R25 | Pot,Wire-wound, 1 kilohm ±1% | 6056-0138 | 11236 | Series 115, Type 115, 1 kilohm ±10% |
| R26 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R27 and R28 | Film, 133 kilohms ±1% 1/8 W | 6250-3133 | 75042 | CEA, 133 kilohms ±1% |
| R29 | Comp., 10 megohms ±5% 1/4 W | 6099-6105 | 01121 | RCR07G106J |
| R41 | Film, 1 kilohm ±0.1% 50 ppm 1/8 W | 6190-2330 | 75042 | CEA, 1 kilohm ±0.1% 50 ppm |
| R42 | Film, 10 kilohms ±0.1% 50 ppm 1/8 W | 6190-5660 | 75042 | CEA, 10 kilohms ±0.1% 50 ppm |
| R43 and R44 | Film, 9 kilohms ±0.1% 50 ppm 1/8 W | 6190-5330 | 75042 | MEA, 9 kilohms ±0.1% 50 ppm |
| R45 | Film, 1 kilohm ±0.1% 50 ppm 1/8 W | 6190-2330 | 75042 | CEA, 1 kilohm ±0.1% 50 ppm |
| R46 | Comp., 10 megohms ±5% 1/4 W | 6099-6105 | 01121 | RCR07G106J |
| R47 | Pot,Cer., 100 kilohms ±20% | 6049-0431 | 80294 | 3299W, 100 kilohms ±20% |
| R58 | Comp., 1 Gigohm, ±20% 1/2 W | 6100-8108 | 01121 | RCR20G108 |
| R59 and R60 | Comp., 100 kilohms ±20% | 6040-1000 | 01121 | YR104M |
| R61 | Comp., 10 megohms ±5% 1/4 W | 6099-6105 | 01121 | RCR07G106J |
| R62 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R70 | Power, wire-wound, 27 ohms ±5% 5 W | 6660-0275 | 75042 | AS-5, 27 ohms ±5% |
| R71 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R72 and R73 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R74 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R75 | Power, wire-wound, 27 ohms ±5% 5 W | 6660-0275 | 75042 | AS-5, 270 ohms ±5% |
| R76 and R77 | Wire-wound,molded, 3 ohms ±10% | 6760-9309 | 75042 | BWH, 3 ohms ±10% |
| R81 | Film, 5 kilohms ±0.1% 15 ppm | 6619-3452 | 75042 | MAR-7, 5 kilohms ±0.1% 15 ppm |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | POTENTIOMETER BOARD (P/N 1685-4740) PARTS | | | |
| RESISTORS | | | | |
| R101 | Wire-wound, rect, 500 ohms ±10% | 6051-1509 | 80294 | 3005-P-1-501 |
| R102 | Wire-wound, rect, 1 kilohm ±10% | 6051-2109 | 80294 | 3005-P-1-102 |
| R103 | Wire-wound, rect, 500 ohms ±10% | 6051-1509 | 80294 | 3005-P-1-501 |
| R104 | Wire-wound, rect, 1 kilohm ±10% | 6051-2109 | 80294 | 3005-P-1-102 |
| R105 | Wire-wound, rect, 500 ohms ±10% | 6051-1509 | 80294 | 3005-P-1-501 |
| R106 and R107 | Wire-wound, rect, 10 kilohms ±10% | 6051-3109 | 80294 | 3005-P-1-103 |
| R108 thru R111 | Wire-wound, rect, 2 kilohms ±10% | 6051-2209 | 80294 | 3005-P-1-202 |
| R112 | Wire-wound, rect, 5 kilohms ±10% | 6051-2509 | 80294 | 3005-P-1-502 |
| R113 | Wire-wound, rect, 2 kilohms ±10% | 6051-2209 | 80294 | 3005-P-1-202 |




Potentiometer etched-circuit board (P/N 1685-4740) layout.

**NOTE:** *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

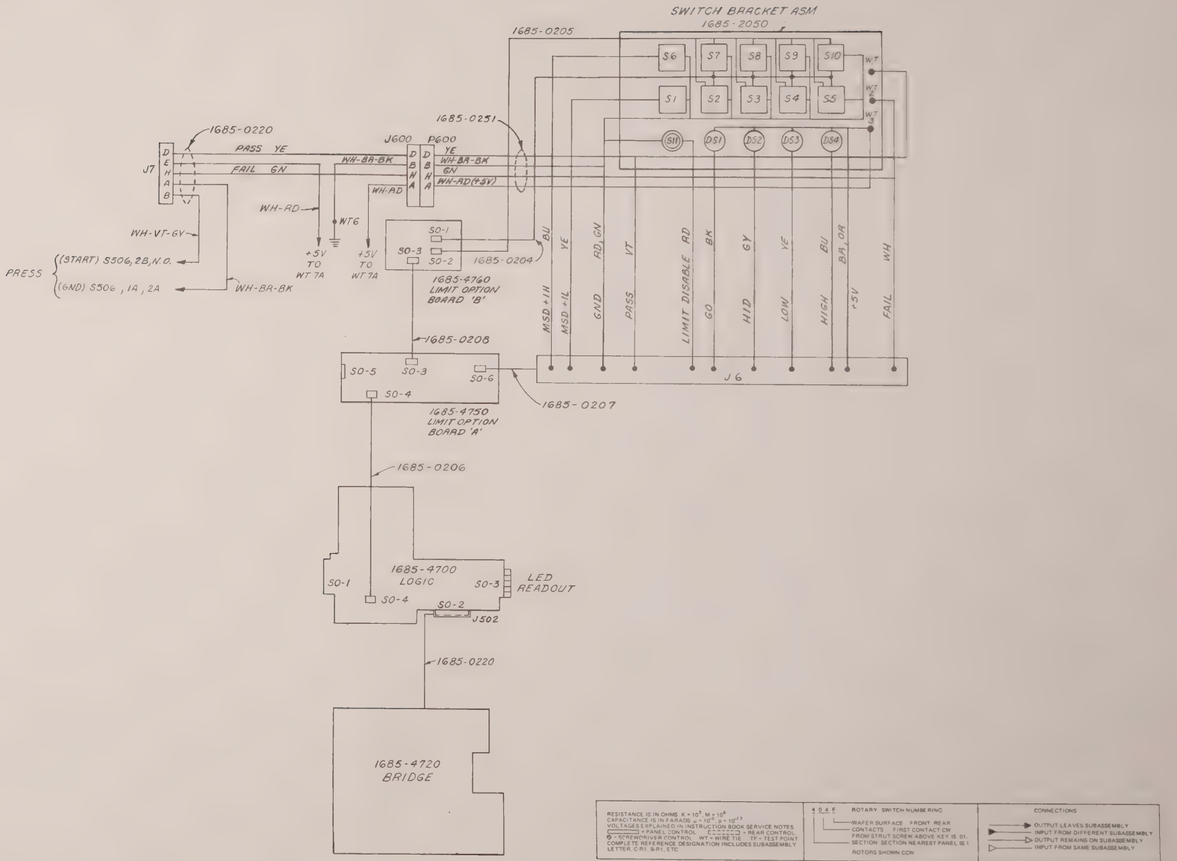



Figure 6-3. Impedance Meter and Limit Comparator interconnection diagram.

1685 DIGITAL IMPEDANCE METER
BRIDGE BOARD WAVEFORMS

R-DC MEASUREMENT MODE

FIGURES 1 THRU 4 SHOW THE 1685-4720 BRIDGE BOARD TIME-RELATED WAVEFORMS, THE TEST POINTS AT WHICH THE WAVEFORMS ARE OBSERVED, AND SCOPE SETTINGS FOR AN R-DC MEASUREMENT OF A STANDARD 10-KΩ RESISTOR ON THE MEASUREMENT CABLE A OR A 1685-P1 TEST FIXTURE.

TO OBTAIN THE REQUIRED WAVEFORMS FOR R-DC:

A. SET THE 1685 SWITCHES TO THE FOLLOWING POSITIONS:
   - PARAMETER----------R DC
   - MODE----------REPETITIVE, 0.25 SEC.
   - RANGE----------6
   - EXTERNAL BIAS----------OFF
   - D-Q DIAL----------D=0.1

B. USE 1440, 10-KΩ STANDARD):

C. SET THE SCOPE SWITCHES TO:
   - MODE----------ALT
   - TRIG----------CH 1

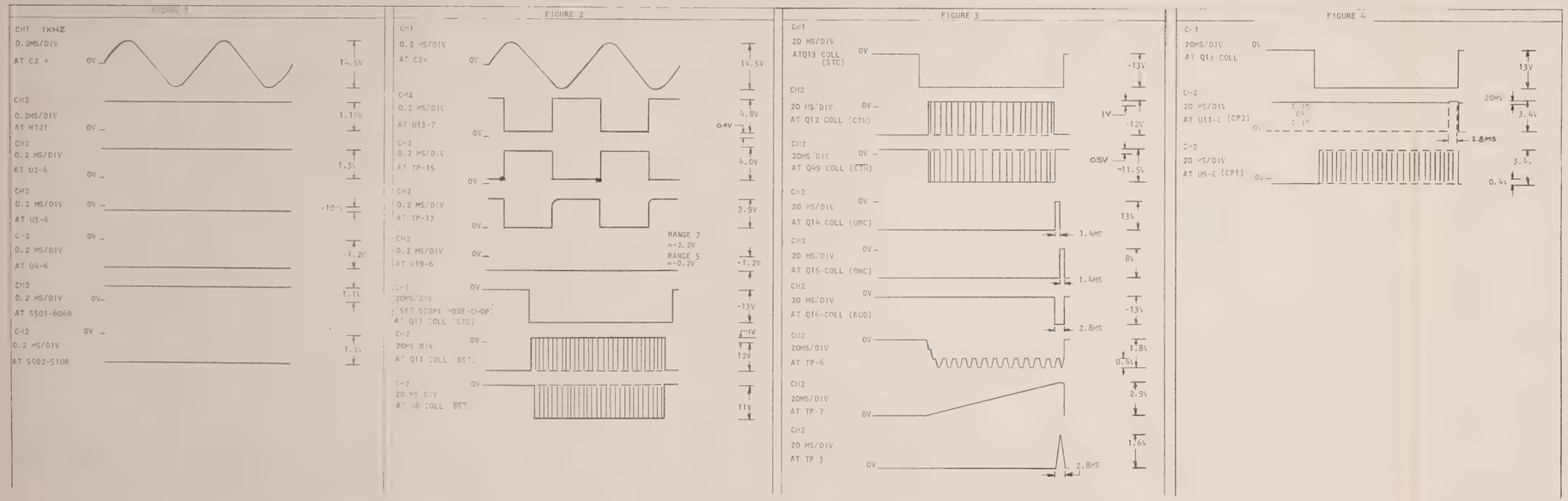
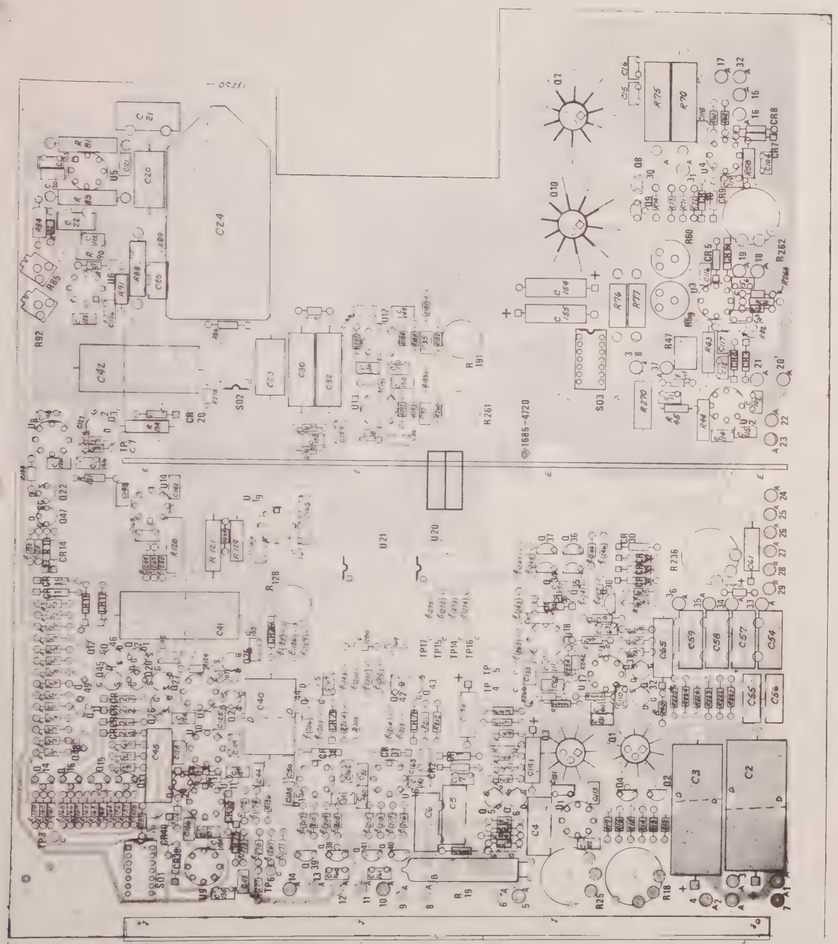



Figure 6-4. Bridge board schematic diagram (sheet 1 of 4).

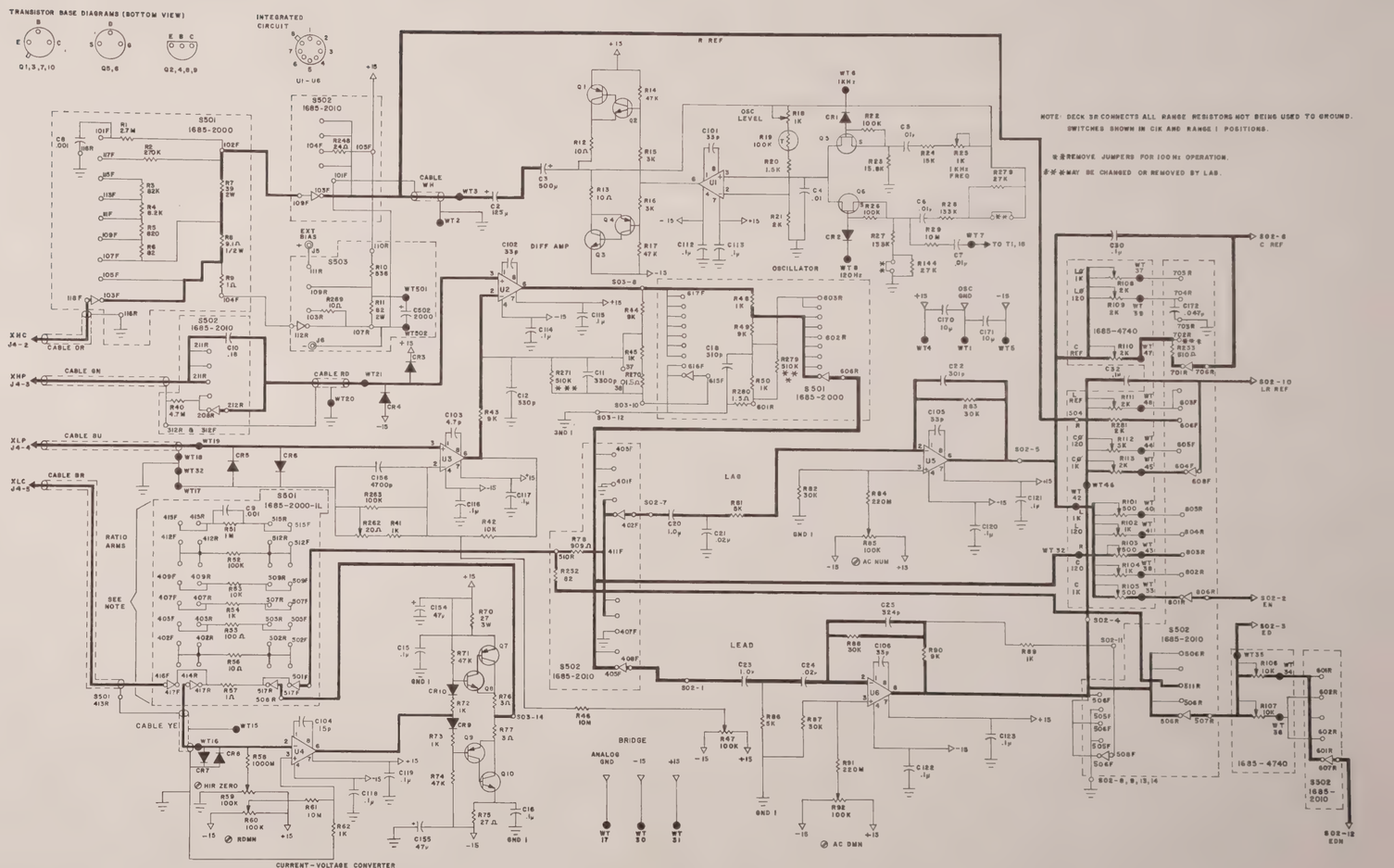
## BRIDGE BOARD SIGNAL NAMES

| Signal Name | Signal Location | Signal Function |
|---|---|---|
| REF | TP 17 | **REFERENCE PULSE** to logic board. 1 kHz to C-1K, R-DC and L-1K. 120 Hz to C-120 and L-120. Generates burst pulse. |
| STC | S01-11 | **START COUNT.** Enables main dual slope integrator (U7) and denominator integrator (U8). |
| BST | S01-2 | **BURST PULSES.** 200 pulses for C-1K, R-DC and L-1K. 20 pulses for C-120 and L-120. Establish measurement time and gate input to integrators. |
| CP1 | U9-6 | **CLOCK PULSE 1.** Comparator output signifies threshold crossover. Generates CTN. |
| CTN | S01-1 | **COUNT N.** Determines the number of 100's count to logic board. Enables $E_{dn}$ input to main dual slope integrator U7. |
| SUD | S01-13 | **START UP-DOWN.** Enables up-down dual slope integrator (U10) for remainder conversion (units and tens digits readout). |
| UPC | S01-14 | **UP COUNT.** Enables remainder input (Q26) to up-down integrator for a specified time (100-count oscillator pulses). |
| DNC | S01-12 | **DOWN COUNT.** Enables denominator input (Q27) to up-down integrator for units and tens digits readout on logic board. |
| CP2 | S01-7 | **CLOCK PULSE 2.** Comparator output signifies DNC complete (0-V threshold). End of measurement. |
| CC | TP 15 | **COUNT COMPLETE.** End of measurement; enables NV flip-flop. |
| NV | TP 21 | **NEW VALUE.** Signifies the new value is in counters U3, U2, U8, U9, and U26. |
| SDL | TP 22 | **SET DATA LATCH.** Loads counter outputs into latches U15, U10, U9, U14 and U25. |
| $\overline{D1}$ | TP 20 | **DIGIT 1.** Strobes LED readout No. 1. |
| $\overline{D2}$ | TP 19 | **DIGIT 2.** Strobes LED readout No. 2. |
| $\overline{D3}$ | TP 18 | **DIGIT 3.** Strobes LED readout No. 3. |
| $\overline{D4}$ | TP 17 | **DIGIT 4.** Strobes LED readout No. 4. |
| RESET | TP 1 | **RESET.** Clear counters and starts new measurement. |



NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

Bridge etched-circuit board (P/N 1685-4720) layout.




REMOVE JUMPERS FOR 100 Hz OPERATION.

MAY BE CHANGED OR REMOVED BY LAB.

RESISTANCE IS IN OHMS, K = $10^3$, M = $10^6$
CAPACITANCE IS IN FARADS, μ = $10^{-6}$, p = $10^{-12}$
VOLTAGES EXPLAINED IN INSTRUCTION BOOK SERVICE NOTES
ROTARY SWITCH NUMBERING: F = FRONT OF SECTION, R = REAR CONTROL
⊕ = SCREWDRIVER CONTROL. WT = WIRE TIE. TP = TEST POINT
COMPLETE REFERENCE DESIGNATION INCLUDES SUBASSEMBLY LETTER, C-R1, R-R1, ETC.

ROTARY SWITCH NUMBERING: 4 0.4 F — WAFER SURFACE FRONT, REAR; CONTACTS FIRST CONTACT CW FROM STRUT SCREW ABOVE KEY IS 01; SECTION SECTION NEAREST PANEL IS 1. ROTORS SHOWN CCW

CONNECTIONS: OUTPUT LEAVES SUBASSEMBLY; INPUT FROM DIFFERENT SUBASSEMBLY; OUTPUT REMAINS ON SUBASSEMBLY; INPUT FROM SAME SUBASSEMBLY

Figure 6-4. Bridge board schematic diagram (sheet 2 of 4).

1685 DIGITAL IMPEDANCE METER
BRIDGE-BOARD WAVEFORMS
1685-3000

Figures 5 thru 9 show the time related waveforms, test points at which the waveforms are observed, and scope, settings for a C-1K measurement of standard 0.1-μF capacitor.

NOTE: With a 1685-P1 or measurement cable with a 0.1-μF standard capacitor and a series 3.3-kΩ resistor connected, only slightly different wave waveforms will be observed.

To obtain the required waveforms:

A. Set 1685 switches to the following positions:
Frequency ---------- C-1K
Mode ---------- REPETITIVE, 0.25 SEC
Range ---------- 5
External bias ---------- OFF
D Dial ---------- D=0.1

B. Use the 3.3-kΩ resistor in series with a GR 1409-T (0.1 μF)

C. Set the scope switches to:
MODE ---------- ALT
TRIG ---------- CH1

FIGURE 5

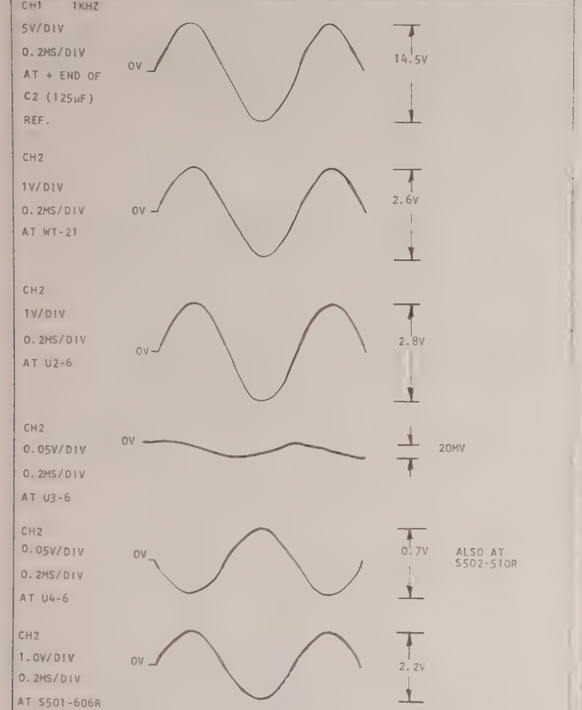



FIGURE 6

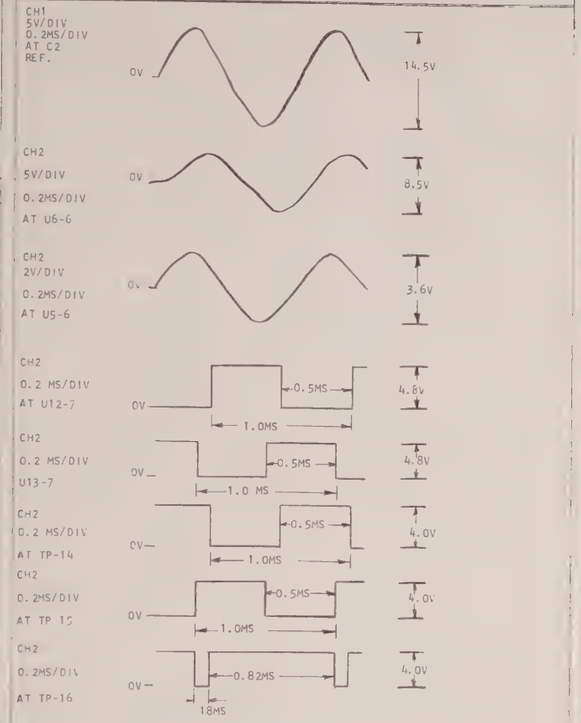



FIGURE 7

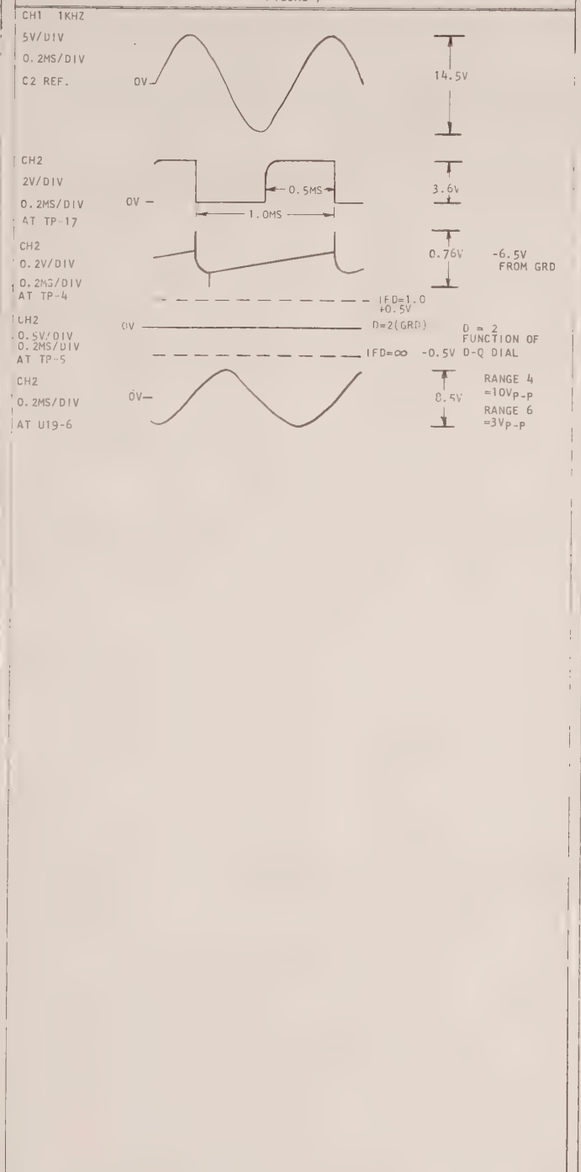



FIGURE 8

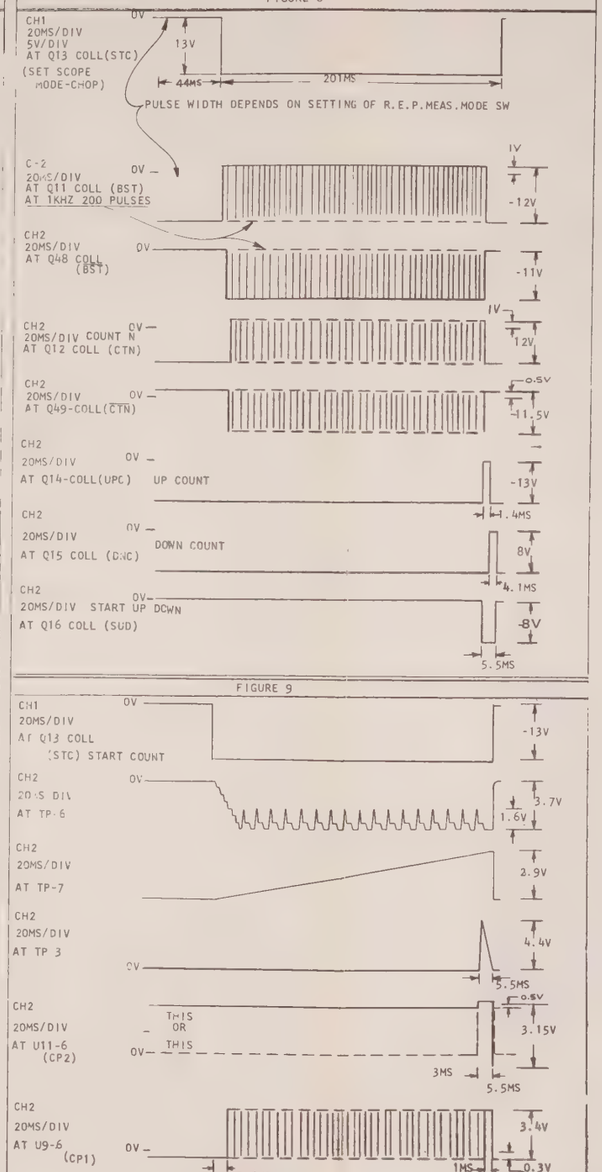



FIGURE 9




Figure 6-4. Bridge board schematic diagram (sheet 3 of 4).

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | BRIDGE BOARD (P/N 1685-4720) PARTS (CONT) | | | |
| RESISTORS (cont) | | | | |
| R82 | Comp., 30 kilohms ±5% 1/4 W | 6099-3305 | 01121 | RCR07G303J |
| R83 | Film, 30 kilohms ±0.1% 15 ppm | 6619-3453 | 75042 | MAR-7, 30 kilohms ±0.1% 15 ppm |
| R84 | Comp., 220 megohms ±10% 1/2 W | 6100-7228 | 01121 | RCR20G227K |
| R85 | Pot., Cer., 100 kilohms ±10% | 6049-0301 | 80294 | 3329W, 100 kilohms ±10% |
| R86 | Film, 5 kilohms ±1% 50 ppm 1/2 W | 6619-1730 | 75042 | CEA, 5 kilohms ±1% 50 ppm |
| R87 | Comp., 30 kilohms ±5% 1/4 W | 6099-3305 | 01121 | RCR07G303J |
| R88 | Film, 30 kilohms ±0.1% 15 ppm | 6619-3453 | 75042 | MAR-7, 30 kilohms ±0.1% 15 ppm |
| R89 | Film, 1 kilohm ±0.1% 50 ppm 1/8 W | 6190-2330 | 75042 | CEA, 1 kilohm ±0.1% 50 ppm |
| R90 | Film, 9 kilohms ±0.1% 50 ppm 1/8 W | 6190-5330 | 75042 | MEA, 9 kilohms ±0.1% 50 ppm |
| R91 | Comp., 220 megohms ±10% 1/2 W | 6100-7228 | 01121 | RCR20G227K |
| R92 | Pot., Cer., 100 kilohms ±10% | 6049-0301 | 80294 | 3329W, 100 kilohms ±10% |
| R120 | Film, 20 kilohms ±0.1% 15 ppm 1/8 W | 6619-3454 | 75042 | MAR-7, 20 kilohms ±0.1% 15 ppm |
| R121 | Film, 10 kilohms ±0.5% 15 ppm 1/2 W | 6619-3450 | 75042 | MAR-7, 10 kilohms ±.05% 15 ppm |
| R122 and R123 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R124 and R125 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R126 | Comp., 470 megohms ±20% 1/4 W | 6099-7478 | 01121 | RCR07G477 |
| R127 | Comp., 39 kilohms ±5% 1/4 W | 6099-3395 | 01121 | RCR07G393J |
| R128 | Pot.,Comp., 100 kilohms ±20% | 6040-1000 | 01121 | YR104M |
| R129 | Film, 402 kilohms ±1% 1/4 W | 6350-3402 | 75042 | CEB, 402 kilohms ±1% |
| R131 | Film, 84.5 kilohms ±1% 1/2 W | 6250-2845 | 75042 | CEA, 84.5 kilohms ±1% |
| R132 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R133 | Comp., 160 kilohms ±5% 1/4 W | 6099-4165 | 01121 | RCR07G164J |
| R134 | Film, 24.9 kilohms ±1% 1/4 W | 6350-2249 | 75042 | CEB, 24.9 kilohms ±1% |
| R135 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R136 | Film, 10.0 kilohms ±1% 1/8 W | 6250-2100 | 75042 | CEA, 10 kilohms ±1% |
| R137 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R138 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R140 | Comp., 20 kilohms ±5% 1/4W | 6099-3205 | 01121 | RCR07G203 |
| R141 and R142 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R143 | Comp., 100 ohms ±5% 1/4 W | 6099-1105 | 01121 | RCR07G101J |
| R144 | Comp., 27 kilohms ±5% 1/4 W | 6099-3275 | 01121 | RCR07G273J |
| R150 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R152 and R153 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R155 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R156 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R157 | Comp., 68 kilohms ±5% 1/4 W | 6099-3685 | 01121 | RCR07G683J |
| R158 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R159 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R160 | Comp., 68 kilohms ±5% 1/4 W | 6099-3685 | 01121 | RCR07G683J |
| R161 | Comp., 4.7 kilohms ±5% 1/4 W | 6099-2475 | 01121 | RCR07G472J |
| R162 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R163 | Comp., 68 kilohms ±5% 1/4 W | 6099-3685 | 01121 | RCR07G683J |

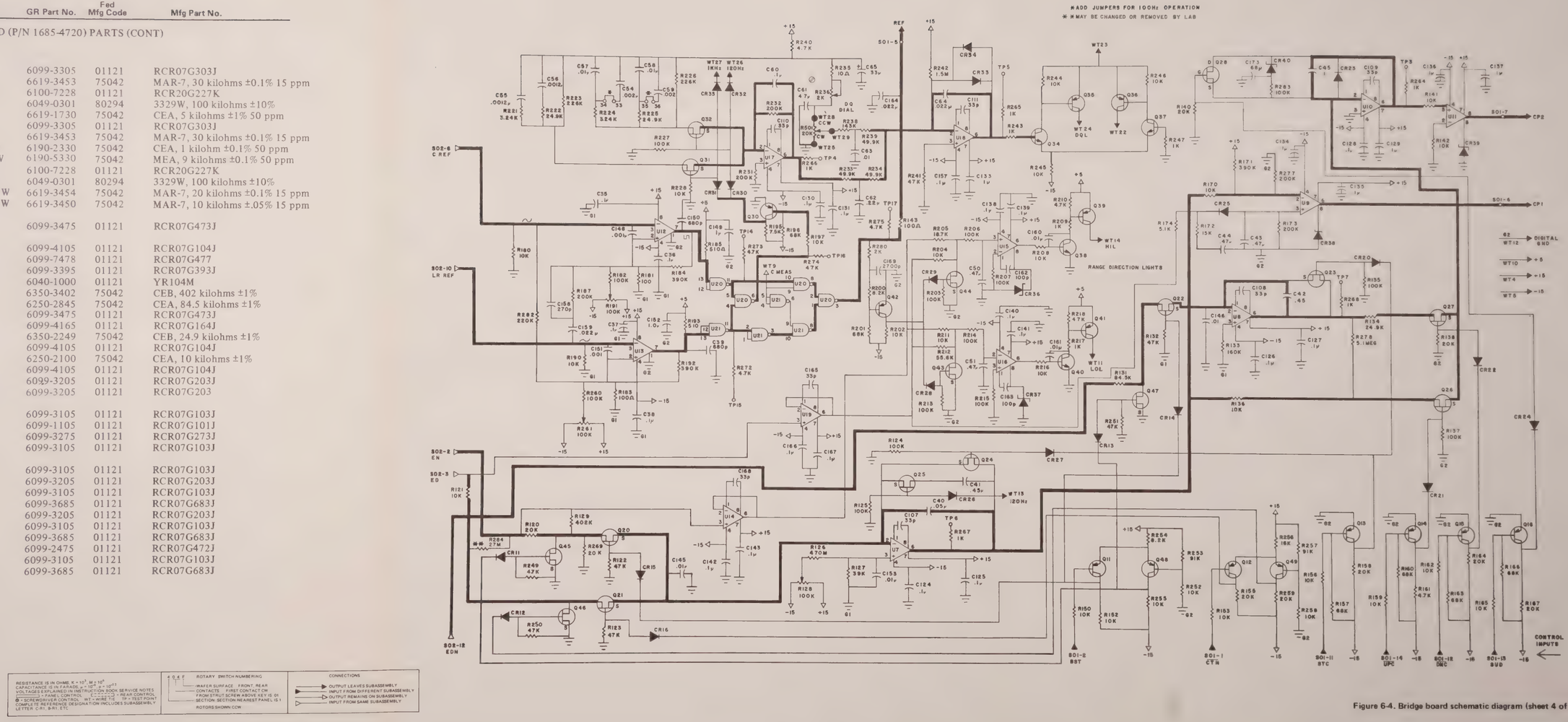



Figure 6-4. Bridge board schematic diagram (sheet 4 of 4).

## ELECTRICAL PARTS LIST

BRIDGE BOARD (P/N 1685-4720) PARTS (CONT)

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| RESISTORS (cont) | | | | |
| R164 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R165 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R166 | Comp., 68 kilohms ±5% 1/4 W | 6099-3685 | 01121 | RCR07G683J |
| R167 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R170 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R171 | Comp., 390 kilohms ±5% 1/4 W | 6099-4395 | 01121 | RCR07G394J |
| R172 | Comp., 15 kilohms ±5% 1/4 W | 6099-3155 | 01121 | RCR07G153J |
| R173 | Comp., 200 kilohms ±5% 1/4 W | 6099-4205 | 01121 | RCR07G204J |
| R174 | Comp., 5.1 kilohms ±5% 1/4 W | 6099-2515 | 01121 | RCR07G512J |
| R180 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R181 | Comp., 100 ohms ±5% 1/4 W | 6099-1105 | 01121 | RCR07G101J |
| R182 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R183 | Comp., 100 ohms ±5% 1/4 W | 6099-1105 | 01121 | RCR07G101J |
| R184 | Comp., 390 kilohms ±5% 1/4 W | 6099-4395 | 01121 | RCR07G394J |
| R185 | Comp., 510 ohms ±5% 1/4 W | 6099-1515 | 01121 | RCR07G511J |
| R187 | Comp., 200 kilohms ±5% 1/4 W | 6099-4205 | 01121 | RCR07G204J |
| R190 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R191 | Pot. Comp., 100 kilohms ±20% | 6040-1000 | 01121 | YR104M |
| R192 | Comp., 390 kilohms ±5% 1/4 W | 6099-4395 | 01121 | RCR07G394J |
| R193 | Comp., 510 ohms ±5% 1/4 W | 6099-1515 | 01121 | RCR07G511J |
| R195 | Comp., 7.5 kilohms ±5% 1/4W | 6099-2755 | 01121 | RCR07G752 |
| R196 | Comp., 68 kilohms ±5% 1/4 W | 6099-3685 | 01121 | RCR07G683J |
| R197 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R200 | Comp., 8.2 kilohms ±5% 1/4 W | 6099-2825 | 01121 | RCR07G822J |
| R201 | Comp., 68 kilohms ±5% 1/4 W | 6099-3685 | 01121 | RCR07G683J |
| R202 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R203 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R204 | Film, 10 kilohms ±1% 1/8 W | 6250-2100 | 75042 | CEA, 10 kilohms ±1% |
| R205 | Film, 18.7 kilohms ±1% 1/8 W | 6250-2187 | 75042 | CEA, 18.7 kilohms ±1% |
| R206 and R207 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R208 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R209 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R210 | Comp., 4.7 kilohms ±5% 1/4 W | 6099-2475 | 01121 | RCR07G472J |
| R211 | Film, 10 kilohms ±1% 1/8 W | 6250-2100 | 75042 | CEA, 10 kilohms ±1% |
| R212 | Film, 55.6 kilohms ±0.5% 1/8 W | 6251-2556 | 75042 | CEA, 55.6 kilohms ±0.5% |
| R213 thru R215 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R216 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R217 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R218 | Comp., 4.7 kilohms ±5% 1/4 W | 6099-2475 | 01121 | RCR07G472J |
| R221 | Film, 3.24 kilohms ±1% 1/8 W | 6250-1324 | 75042 | CEA, 3.24 kilohms ±1% |
| R222 | Film, 24.9 kilohms ±1% 1/8 W | 6250-2249 | 75042 | CEA, 24.9 kilohms ±1% |
| R223 | Film, 226 kilohms ±1% 1/8 W | 6250-3226 | 75042 | CEA, 226 kilohms ±1% |
| R224 | Film, 3.24 kilohms ±1% 1/8 W | 6250-1324 | 75042 | CEA, 3.24 kilohms ±1% |
| R225 | Film, 24.9 kilohms ±1% 1/8 W | 6250-2249 | 75042 | CEA, 24.9 kilohms ±1% |
| R226 | Film, 226 kilohms ±1% 1/8 W | 6250-3226 | 75042 | CEA, 226 kilohms ±1% |
| R227 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R228 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R231 | Comp., 200 kilohms ±5% 1/4 W | 6099-4205 | 01121 | RCR07G204J |
| R232 | Film, 200 kilohms ±1% 1/8 W | 6250-3200 | 75042 | CEA, 200 kilohms ±1% |
| R233 and R234 | Film, 49.9 kilohms ±1% 1/8 W | 6250-2499 | 75042 | CEA, 49.9 kilohms ±1% |

## ELECTRICAL PARTS LIST

BRIDGE BOARD (P/N 1685-4720) PARTS (CONT)

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| RESISTORS (cont) | | | | |
| R235 | Comp., 10 ohms ±5% 1/4 W | 6099-0105 | 01121d | RCR07G100J |
| R236 | Pot., Wire-wound, 2 kilohms ±10% | 6056-0140 | 11236 | Series 115, Type 115, 2 kilohms ±10% |
| R238 | Film, 143 kilohms ±1% 1/8 W | 6250-3143 | 75042 | CEA, 143 kilohms ±1% |
| R239 | Film, 49.9 kilohms ±1% 1/8 W | 6250-2499 | 75042 | CEA, 49.9 kilohms ±1% |
| R240 | Comp., 4.7 kilohms ±5% 1/4 W | 6099-2475 | 01121 | RCR07G472J |
| R241 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R242 | Comp., 1.5 megohms ±5% 1/4 W | 6099-5155 | 01121 | RCR07G155J |
| R243 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R244 thru R246 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R247 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R249 thru R251 | Comp., 47 kilohms ±5% 1/4 W | 6099-3475 | 01121 | RCR07G473J |
| R252 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R253 | Comp., 91 kilohms ±5% 1/4 W | 6099-3915 | 01121 | RCR07G913J |
| R254 | Comp., 8.2 kilohms ±5% 1/4 W | 6099-2825 | 01121 | RCR07G822J |
| R255 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R256 | Comp., 16 kilohms ±5% 1/4 W | 6099-3165 | 01121 | RCR07G163J |
| R257 | Comp., 91 kilohms ±5% 1/4 W | 6099-3915 | 01121 | RCR07G913J |
| R258 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R259 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R260 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R261 | Pot., Comp., 100 kilohms ±20% | 6040-1000 | 01121 | YR104M |
| R262 | Pot., Wire-wound, 20 ohms ±10% | 6056-0128 | 11236 | Series 115, Type 115, 20 ohms ±10% |
| R263 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R264 thru R268 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R269 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R270 | Wire-wound, 1.5 ohms | 6760-9159 | 75042 | BWH, 3 ohms ±10% |
| R271 | Comp., 510 kilohms ±5% 1/4 W | 6099-4515 | 01121 | RCR07G514J |
| R272 thru R275 | Comp., 4.7 kilohms ±5% 1/4 W | 6099-2475 | 01121 | RCR07G472J |
| R277 | Comp., 200 kilohms ±5% 1/4 W | 6099-4205 | 01121 | RCR07G204J |
| R278 | Comp., 5.1 megohms ±5% 1/4 W | 6099-5515 | 01121 | RCR07G515J |
| R279 | Comp., 27 kilohms ±5% 1/4 W | 6099-3275 | 01121 | RCR07G273 |
| R280 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R282 | Comp., 220 kilohms ±5% 1/4 W | 6099-4225 | 01121 | RCR07G224J |
| R283 | Comp., 100 kilohms ±5% 1/4 W | 6099-4105 | 01121 | RCR07G104J |
| R284 | Comp., 27 megohms ±5% 1/4 W | 6099-6275 | 01121 | RCR07G276J |
| TRANSISTORS | | | | |
| Q1 | Type 2N3467 | 8210-1233 | 04713 | 2N3467 |
| Q2 | Type 2N3903 | 8210-1132 | 04713 | 2N3903 |
| Q3 | Type 2N5189 | 8210-1163 | 02735 | 2N5189 |
| Q4 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |
| Q5 and Q6 | Type E113 | 8210-1229 | 17856 | E113 |
| Q7 | Type 2N3467 | 8210-1233 | 04713 | 2N3467 |
| Q8 | Type 2N3903 | 8210-1132 | 04713 | 2N3903 |
| SOCKETS | | | | |
| S01 thru S03 | 14 Contact, PC | 7540-1815 | 71785 | 133-51-02-003 |

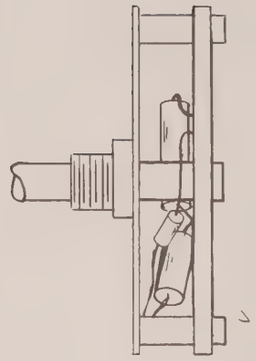
## ELECTRICAL PARTS LIST

BRIDGE BOARD (P/N 1685-4720) PARTS (CONT)

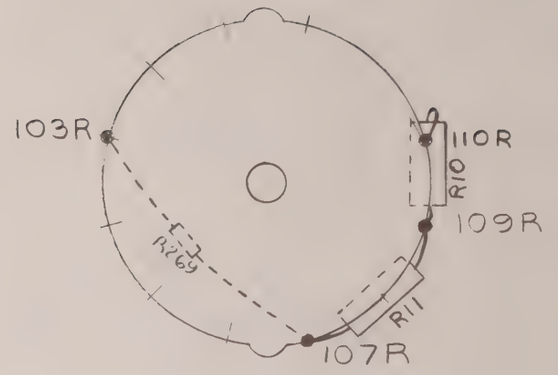
| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| TRANSISTORS (cont) | | | | |
| Q9 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |
| Q10 | Type 2N5189 | 8210-1163 | 02735 | 2N5189 |
| Q11 thru Q16 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |
| Q20 thru Q28 | Type E113 | 8210-1229 | 17856 | E113 |
| Q30 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |
| Q31 and Q32 | Type T1S-74 | 8210-1202 | 01295 | T1S-74 |
| Q34 | Type 2N3903 | 8210-1132 | 04713 | 2N3903 |
| Q35 and Q36 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |
| Q37 and Q38 | Type 2N3903 | 8210-1132 | 04713 | 2N3903 |
| Q39 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |
| Q40 | Type 2N3903 | 8210-1132 | 04713 | 2N3903 |
| Q41 and Q42 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |
| Q43 thru Q47 | Type E113 | 8210-1229 | 17856 | E113 |
| Q48 and Q49 | Type 2N3906 | 8210-1112 | 04713 | 2N3906 |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | CAPACITOR BIAS SWITCH S503 PARTS | | | |
| SWITCH ASSEMBLY | | 1685-2040 | 24655 | 1685-2040 |
| RESISTORS | | | | |
| R10 | Film, 536 ohms ±1% 1/2 W | 6450-0536 | 12928 | CEC, 536 ohms ±1% |
| R11 | Wire-wound, 82 ohms ±5% 2 W | 6760-0825 | 75042 | BWH, 82 ohms ±5% |
| R269 | Comp., 10 ohms ±5% 1/4 W | 6099-0105 | 01121 | RCR07G100J |
| SWITCH | | | | |
| S503 | Rotary, wafer | 7890-5622 | 24655 | 7890-5622 |



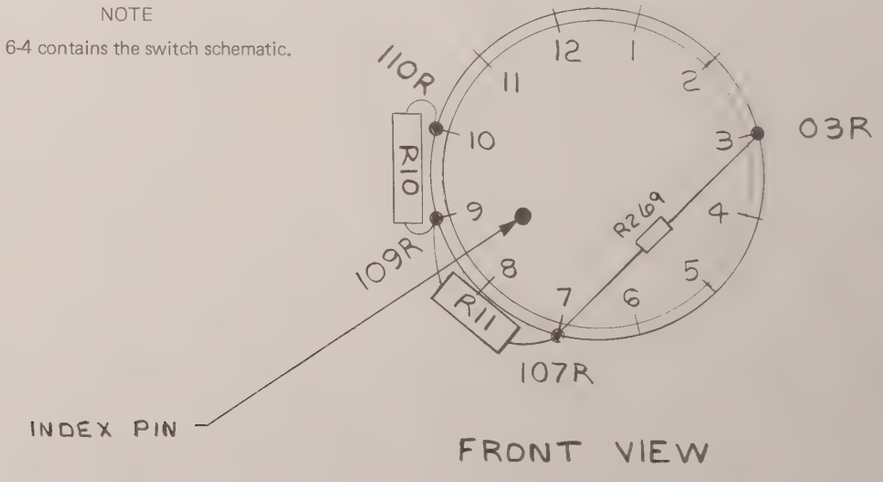
S-503




S-503, 103R TO S-503, 107R BY R269
S-503, 107R TO S-503, 109R BY R11
S-503, 109R TO S-503, 110R BY R10

NOTE

Figure 6-4 contains the switch schematic.




FRONT VIEW

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

**Figure 6-5. Capacitor bias switch S503 layout drawing showing parts.**

S502, 104F TO S502, 105F BY R248
S502, 211R TO S502, 212R BY C10
S502, 208R TO S502, 312F,R BY R40
S502, 302F TO S502, 302R
S502, 302F,R TO S502, 403R
S502, 309F TO S502, 309R
S502, 309F,R TO S502, 409R
S502, 306F TO S502, 306R
S502, 306F,R TO S502, 406R

S502, 402R TO S502, 404R
S502, 201F TO S502, 301F BY R251
S502, 301F TO S502, 712F
S502, 807F TO S502, 808F BY R249
S502, 807F TO S502, 809F BY R250
S502, 411F TO S502, 510R BY R78
S502, 708R TO S502, 704R BY C172
S502, 506F TO S502, 506R
S502, 103F,R TO S502, 504R
S502, 101F TO S502, 401F
S502, 401F TO S502, 407F
S502, 505F TO S502, 703R
S502, 701R TO S502, 702R BY R253
S502, 504R TO S502, 606F BY R281
S502, 510R TO S502, 511R BY R252

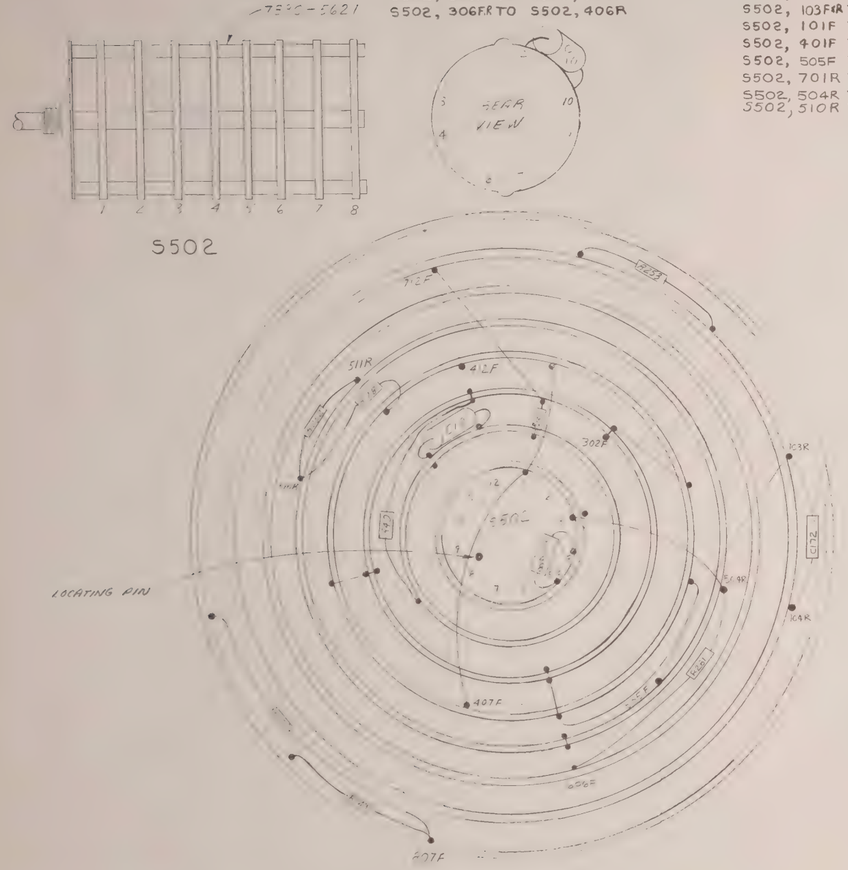
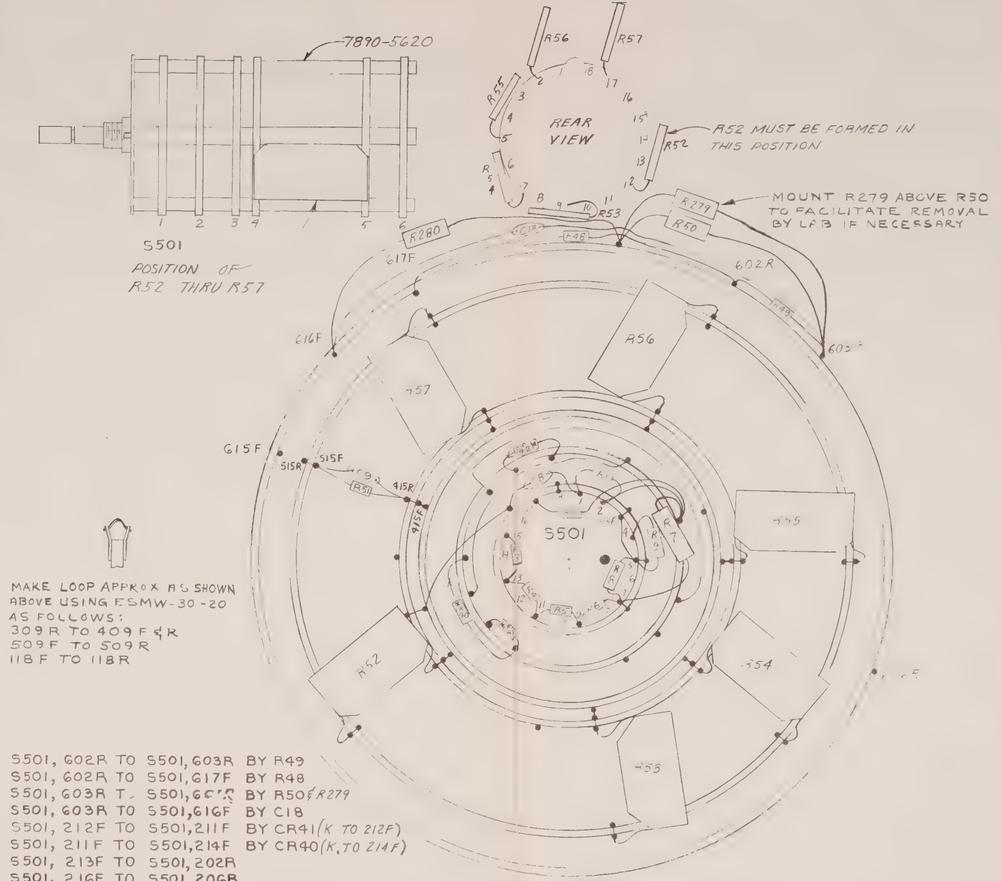



Figure 6-6. Parameter switch S502 layout drawing.




S501, 602R TO S501, 603R BY R49
S501, 602R TO S501, 617F BY R48
S501, 603R TO S501, 616F BY R50 & R279
S501, 603R TO S501, 616F BY C18
S501, 212F TO S501, 211F BY CR41 (K TO 212F)
S501, 211F TO S501, 214F BY CR40 (K TO 214F)
S501, 213F TO S501, 202R
S501, 216F TO S501, 206R
S501, 217F TO S501, 218F BY CR42 (K TO 217F)
S501, 601R TO S501, 616F BY R280
S501, 102F TO S501, 204R
S501, 103F TO S501, 105F
S501, 107F TO S501, 109F BY R6
S501, 109F TO S501, 111F BY R5
S501, 111F TO S501, 113F BY R4
S501, 113F TO S501, 115F BY R3
S501, 104F TO S501, 105F BY R9

S501, 105F TO S501, 107F BY R8
S501, 107F TO S501, 204R BY R7
S501, 101F TO S501, 102F BY R1
S501, 204R TO S501, 117F BY R2
S501, 307R TO S501, 407F,R TO S501, 507F,R BY R54
S501, 305R TO S501, 405F,R TO S501, 505F,R BY R55
S501, 302R TO S501, 402F,R TO S501, 502F,R BY R56
S501, 317R TO S501, 417F,R TO S501, 517F,R BY R57
S501, 116R TO S501, 313R TO S501, 413R

Rotary switch sections are shown as viewed from the panel end of the shaft. The first digit of the contact number refers to the section. The section nearest the panel is 1, the next section back is 2, etc. The next two digits refer to the contact. Contact 01 is the first position clockwise from a strut screw (usually the screw above the locating key), and the other contacts are numbered sequentially (02, 03, 04, etc), proceeding clockwise around the section. A suffix F or R indicates that the contact is on the front or rear of the section, respectively.

S501, 101F TO S501, 116R BY C8
S501, 315R TO S501, 415F,R TO S501, 515F,R BY R51 & C9
S501, 312R TO S501, 412F,R TO S501, 512F,R BY R52
S501, 309R TO S501, 409F,R TO S501, 509F,R BY R53

Figure 6-7. Range switch S501 layout drawing.

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | **RANGE SWITCH S501 PARTS** | | | |
| | **CAPACITORS** | | | |
| C8 and C9 | Ceramic, 1000 pF ±5% | 4405-2105 | 72982 | 801, 1000 pF ±5% |
| C18 | Ceramic, 510 pF ±10% 500 V | 4404-1519 | 72982 | 831, 510 pF ±10% |
| | **DIODES** | | | |
| CR40 thru CR42 | Type 1N455 | 6082-1010 | 14433 | 1N455 |
| | **RESISTORS** | | | |
| R1 | Comp., 2.7 megohms ±5% 1/4 W | 6099-5275 | 01121 | RCR07G275J |
| R2 | Comp., 270 kilohms ±5% 1/4 W | 6099-4275 | 01121 | RCR07G274J |
| R3 | Comp., 82 kilohms ±5% 1/4 W | 6099-3825 | 01121 | RCR07G823J |
| R4 | Comp., 8.2 kilohms ±5% 1/4 W | 6099-2825 | 01121 | RCR07G822J |
| R5 | Comp., 820 ohms ±5% 1/4 W | 6099-1825 | 01121 | RCR07G821J |
| R6 | Comp., 82 ohms ±5% 1/4 W | 6099-0825 | 01121 | RCR07G820J |
| R7 | Wire-wound, 39 ohms ±5% 2 W | 6760-0395 | 75042 | BWH, 39 ohms ±5% |
| R8 | Comp., 9.1 ohms ±5% 1/2 W | 6100-9915 | 01121 | RCR20G9R1J |
| R9 | Wire-wound, 1 ohm ±5% 2 W | 6760-9105 | 75042 | BWH, 1 ohm ±5% |
| R48 | Film, 1 kilohm ±1% 50 ppm 1/8 W | 6190-2330 | 75042 | CEA, 1 kilohm ±1% 50 ppm |
| R49 | Film, 9 kilohms ±1% 50 ppm 1/8 W | 6190-5535 | 75042 | MEA, 9 kilohms ±1% 50 ppm |
| R50 | Film, 1 kilohm ±1% 50 ppm 1/8 W | 6190-2330 | 75042 | CEA, 1 kilohm ±1% 50 ppm |
| R51 | Film, 1 megohm ±1% 50 ppm 1/2 W | 6188-4100 | 75042 | CEC, 1 megohm ±1% 50 ppm |
| R52 | Wire-wound, 100 kilohms ±.02% 1 W | 6983-6000 | 24655 | 6983-6000 |
| R53 | Wire-wound, 10 kilohms ±.02% 1 W | 6983-5039 | 24655 | 6983-5039 |
| R54 | Wire-wound, 1 kilohm ±.02% 1 W | 6983-4000 | 24655 | 6983-4000 |
| R55 | Wire-wound, 100 ohms ±.025% 1 W | 6983-3000 | 24655 | 6983-3000 |
| R56 | Wire-wound, 10 ohms ±.025% | 6983-2005 | 24655 | 6983-2005 |
| R57 | Wire-wound, 1 ohm ±.05% | 6983-1006 | 24655 | 6983-1006 |
| R279 | Comp., 510 kilohms ±5% 1/4 W | 6099-4515 | 01121 | RCR07G514J |
| R280 | Wire-wound, 1.5 ohms ±10% 2 W | 6760-9159 | 75042 | BWH, 1.5 ohms ±10% |
| | **SWITCH ASSEMBLY** | | | |
| S501 | Switch, Rotary, wafer | 7890-5620 | 24655 | 7890-5620 |
| | **PARAMETER SWITCH S502 PARTS** | | | |
| | **CAPACITORS** | | | |
| C10 | Mylar, 018 uF ±5% 100 V | 4860-7897 | 84411 | 663UW, 0.18 uF ±5% 100 V |
| C172 | Mylar, 047 uF ±10% 100 V | 4860-8200 | 84411 | 663UW, .047 uF ±10% 100 V |
| | **RESISTORS** | | | |
| R40 | Comp., 4.7 megohms, ±5% 1/4 W | 6099-5475 | 01121 | RCR07G475J |
| R78 | Film, 909 ohms, ±1% 1/8 W | 6250-0909 | 75042 | CEA, 909 ohms ±1% 1/8 W |
| R248 | Wire-wound, 24 ohms ±5% 2 W | 6760-0245 | 75042 | BWH, 24 ohms ±5% 2 W |
| R249 and R250 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R251 | Comp., 20 ohms ±5% 1/4 W | 6099-0205 | 01121 | RCR07G200J |
| R252 | Comp., 80 ohms ±5% 1/4 W | 6099-0825 | 01121 | RCR07G820J |
| R253 | Comp., 510 ohms ±5% 1/4 W | 6099-1515 | 01121 | RCR07G511J |
| R281 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| | **SWITCH** | | | |
| S502 | Switch, rotary, wafer | 7890-5621 | 24655 | 7890-5621 |

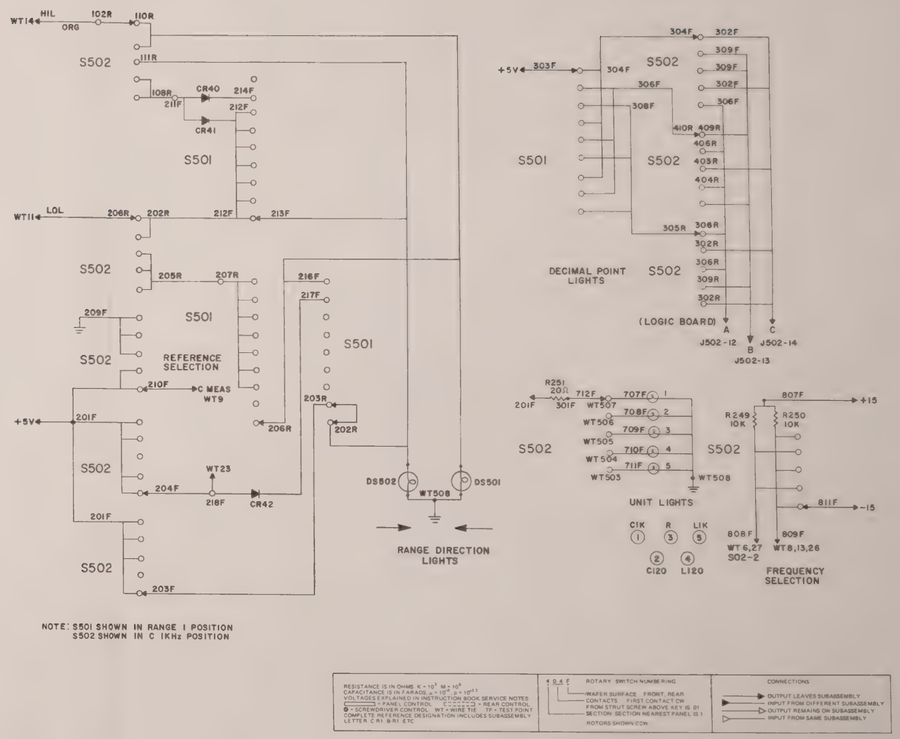
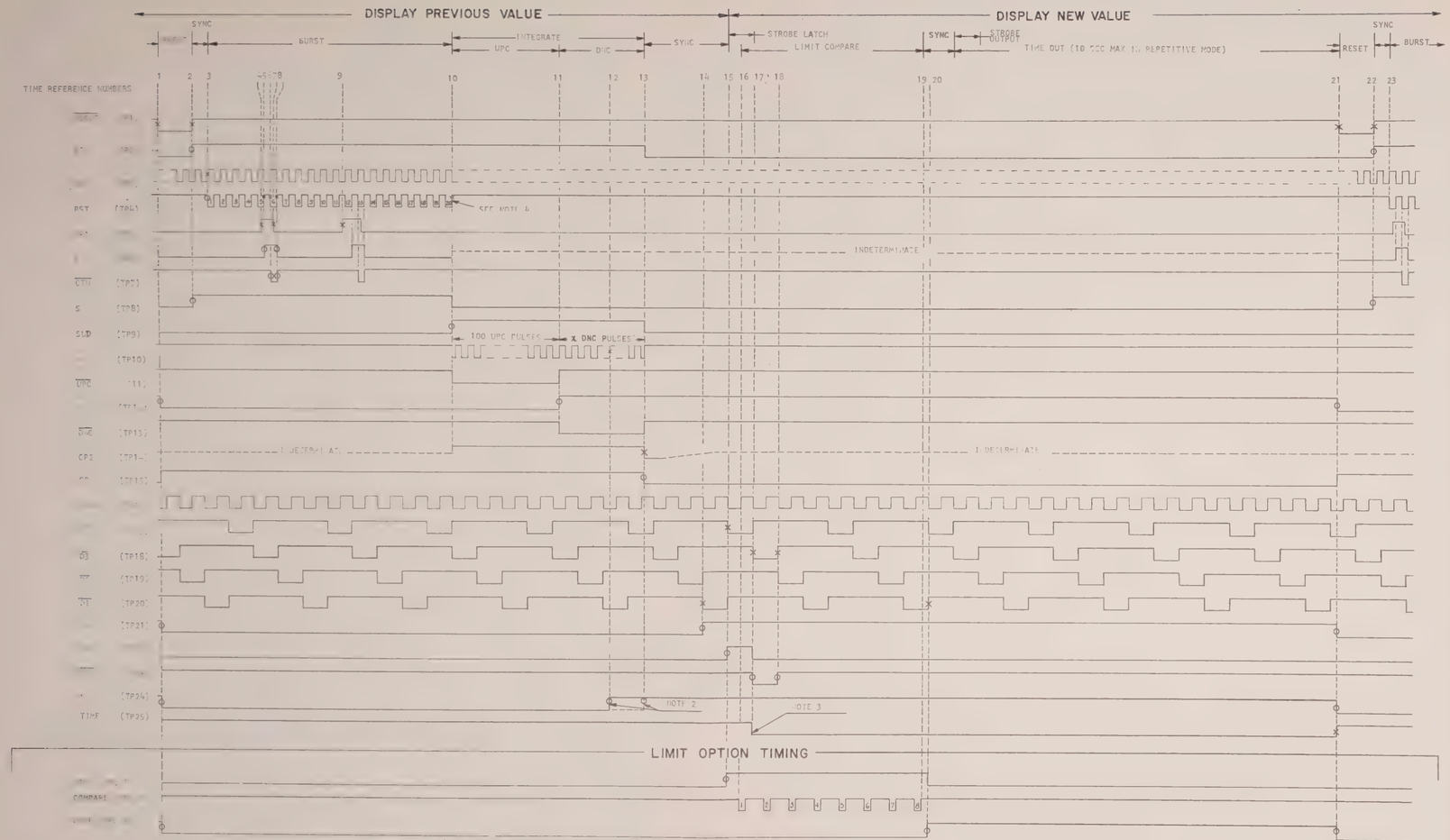



Figure 6-8. Parameter and range switches S502 and S501 schematic diagram.




EDGE ... T-EXTRA ISITION AT THAT POINT IN TIME.

2. THE EARLIEST TIME THAT T IS EDGE CA OCCUR IS ACTIVE 2000 DNC PULSES. THE LATEST TIME IT CAN OCCUR IS SHOWN DOTTED (WHEN "CC" GOES LOW). IF IT HAS NOT OCCURRED BEFORE "CC" GOES LOW, "T" WILL SIMPLY RETAIN LOW.
3. "TIME" IS ACTIVATED BY THE NEGATIVE-GOING EDGE OF "SLD" WHEN THE FRONT PANEL "MODE" SWITCH IS IN THE "REPETITIVE" POSITION.
4. 20 COUNTS WHEN MAKING 120 HZ MEASUREMENTS; 200 COUNTS WHEN MAKING 1KHZ MEASUREMENTS.

**Figure 6-9. System timing diagram.**

FEDERAL MANUFACTURER'S CODE

From Federal Supply Code for Manufacturers Cataloging Handbooks H4-1 (Name to Code) and H4-2 (Code to Name) as supplemented through August, 1968.

| Code | Manufacturer |
|---|---|
| 00136 | McCoy Electronics Co., Mt. Holly Springs, PA 17065 |
| 00192 | Jones Mfg. Co., Chicago, IL 60607 |
| 00194 | Weiseo Electronics Corp., Los Angeles, CA 90063 |
| 00327 | Welwyn International, Westlake, OH 44145 |
| 00434 | Schweber Electronics, Westburg, NY 11590 |
| 00656 | Aerovox Corp., New Bedford, MA 02746 |
| 00779 | Amp, Inc., Harrisburg, PA 17105 |
| 01009 | Alden Products Co., Brockton, MA 02413 |
| 01121 | Allen-Bradley Co./Electronics Div., Milwaukee, WI 53204 |
| 01295 | Litton Industries Inc., Beverly Hills, CA 90213 |
| 01295 | Texas Instruments, Inc., Dallas, TX 75222 |
| 01930 | Amerock, Corp., Rockford, IL 61101 |
| 02111 | Spectrol Electronics Corp., City of Industry, CA 91745 |
| 02114 | Ferroxcube Corp., Saugerties, NY 12477 |
| 02606 | Fenwal Lab Inc., Morton Grove, IL 60053 |
| 02660 | Amphenol Electron Corp., Broadview, IL 60153 |
| 02768 | Fastex, Des Plains, IL 60016 |
| 03042 | Cartier Ink Co., Cambridge, MA 02142 |
| 03508 | G. E. Semicon Prod., Syracuse, NY 13201 |
| 03636 | Grayburne, Yonkers, NY 10701 |
| 03877 | Transitron Electronic, Wakefield, MA 01880 |
| 03911 | Clarex Corp., New York, NY 10001 |
| 04009 | Arrow Hart, Hartford, CT 06106 |
| 04643 | Digitronics Corp., Albertson, NY 11507 |
| 04713 | Motorola, Phoenix, AZ 85008 |
| 04819 | Component Mfg. Service, Inc., West Bridgewater, MA 02379 |
| 06079 | Tansitor Electronics, Bennington, VT 05201 |
| 05402 | Controls Co. of America, Melrose Park, IL 60160 |
| 05574 | Viking Industries, Inc., Chatsworth, CA 91311 |
| 06824 | Barber-Colman Co., Rockford, IL 61101 |
| 06748 | Barnes Mfg. Co., Mansfield, OH 44901 |
| 05820 | Wakefield Engineering Inc., Wakefield, MA 01880 |
| 06743 | Clevite Corp., Cleveland, OH 44110 |
| 07126 | Digitran Co., Pasadena, CA 91106 |
| 07127 | Eagle Signal (E.W. Bliss Co.), Baraboo, WI 53913 |
| 07233 | Cinch Graphic, City of Industry, CA 91744 |
| 07261 | Avnet Corp., Culver City, CA 90230 |
| 07263 | Fairchild Semiconductor, Mountain View, CA 94040 |
| 07387 | Bircher Corp., No. Los Angeles, CA 90032 |
| 07595 | Amer. Semiconductor, Arlington Hts, IL 60004 |
| 07828 | Bodine Corp., Bridgeport, CT 06605 |
| 07829 | Bodine Electric Co., Chicago, IL 60618 |
| 07910 | Cont. Device Corp., Hawthorne, CA 90250 |
| 07983 | State Labs, Inc., New York, NY 10003 |
| 07990 | Borg Instruments, Delavan, WI 53115 |
| 08730 | Vemaline Products Co., Franklin Lakes, NJ 07417 |
| 09213 | G. E. Semiconductor, Buffalo, NY 14207 |
| 09353 | C & K Components Inc., Watertown, MA 02172 |
| 09408 | Star-Tronics Inc., Georgetown, MA 01830 |
| 09823 | Burgess Battery Co., Freeport, IL 61032 |
| 09856 | Fenwal Electronics, Inc., Framingham, MA 01701 |
| 09922 | Burndy Corp., Norwalk, CT 06852 |
| 11236 | CTS of Berne, Inc., Berne, IN 46711 |
| 11599 | Chandler Evans Corp., W. Hartford, CT 06101 |
| 11963 | Nortronics Co., Inc., Minneapolis, MN 55427 |
| 12040 | National Semiconductor, Santa Clara, CA 95051 |
| 12045 | Electronic Transistors Corp., Flushing, NY 11354 |
| 12499 | Teledyne Semiconductor, Mountain View, CA 94043 |
| 12611 | Hamlin, Inc., Lake Mills, WI 53551 |
| 12672 | R. C. A., Woodbridge, NJ 07095 |
| 12897 | Clarostat Mfg. Co., Inc., Dover, NH 03820 |
| 12954 | Dickson Electronics Corp., Scottsdale, AZ 85252 |
| 12968 | Unitrode Corp., Watertown, MA 02172 |
| 13094 | Electrocraft Corp., Hopkins, MN 55343 |
| 13103 | Thermalloy, Inc., Dallas, TX 75234 |
| 13327 | Solitron Devices, Tappan, NY 10983 |
| 13919 | Burr Brown Research Corp., Tucson, AZ 85706 |
| 14155 | Electronic Controls, Inc., Wilton, CT 06897 |
| 14433 | I.T.T. Semiconductors, W. Palm Beach, FL 33402 |
| 14482 | Watkins & Johnson Co., Palo Alto, CA 94304 |
| 14655 | Cornell Dubilier Electronics, Newark, NJ 07101 |
| 14674 | Corning Glass Works, Corning, NY 14830 |
| 14749 | Acoplan, Easton, PA 18042 |
| 14752 | Electro Cube, Inc., San Gabriel, CA 91776 |
| 14936 | General Instrument Corp., Hicksville, NY 11802 |
| 15116 | Microdot Magnetics Inc., Los Angeles, CA 90063 |
| 15238 | I.T.T. Semiconductors, Lawrence, MA 08142 |
| 15478 | Digital Equipment Corp., Maynard, MA 01754 |
| 15605 | Cutler Hammer, Inc., Milwaukee, WI 53202 |
| 15782 | Houston Instrument Corp., Bellaire, TX 77401 |
| 16037 | Spruce Pine Mica Co., Spruce Pine, NC 28777 |
| 16179 | Omni Spectra Mich Div., Farmington, MI 48024 |
| 16352 | Computer Diode Corp., Lodi, NJ 07644 |
| 16636 | Indiana General Corp., Oglesby, IL 61348 |
| 16758 | Delco Electronic Div., GMC, Kokomo, IN 46901 |
| 16960 | Precision Dynamics Corp., Burbank, CA 91504 |
| 16962 | American Micro Devices, Inc., Summerville, SC 29483 |
| 17117 | Electronic Molding Corp., Woonsocket, RI 02895 |
| 17771 | Singer Co., Diehl Div., Somerville, NJ 08876 |
| 17850 | Zeltex, Inc., Concord, CA 94520 |
| 17856 | Siliconix, Inc., Santa Clara, CA 95054 |
| 18324 | Signetics, Corp., Sunnyvale, CA 94086 |
| 18542 | New Product Engineering Inc., Wabash, IN 46992 |
| 18677 | Soanbe Manufacturing Corp., El Monte, CA 91731 |
| 18738 | Voltronics Corp., Hanover, NJ 07936 |
| 18796 | Computer Diode Corp., S. Fairlawn, NJ 07936 |
| 19048 | Computer Diode Corp., S. Fairlawn, NJ 07410 |
| 19178 | Zero Manufacturing Co., Monson, MA 01057 |
| 19373 | Eastron Corp., Haverhill, MA 01830 |
| 19396 | Illinois Tool Works, Pakton Div., Chicago, IL 60634 |
| 19617 | Cabtron Corp., Chicago, IL 60622 |
| 19644 | L.R.C. Electronics, Horseheads, NY 14845 |
| 19701 | Electra Mfg. Co., Independence, KS 67301 |
| 20764 | K.M.C. Semiconductor, Long Valley, NJ 07853 |
| 21335 | Fafnir Bearing Co., New Britain, CT 06050 |
| 21769 | Lanoa-Fugle Electronics, Watchung, NJ 07060 |
| 22753 | UID Electronics Div., AMF Inc., Hollywood, FL 33022 |
| 23338 | Wavetek Div., John Fluke, San Diego, CA 92112 |
| 23342 | Avnet Electronics Corp., Franklin Park, IL 60131 |
| 24355 | Analog Devices, Cambridge, MA 02142 |
| 24446 | General Electric, Schenectady, NY 12305 |
| 24454 | General Electric Electronics Comp., Syracuse, NY 13201 |
| 24455 | General Electric Lamp Div., Cleveland, OH 44112 |
| 24602 | E.M.C. Technology, Cherry Hill, NJ 08034 |
| 24666 | General Radio Co., Concord, MA 01742 |
| 25289 | E.G.&G. Inc., Bedford, MA 01730 |
| 26806 | American Zettler, Inc., Costa Mesa, CA 92626 |
| 28480 | Hewlett Packard, Palo Alto, CA 04304 |
| 28520 | Heyman Mfg. Co., Kenilworth, NJ 07033 |
| 28969 | Hoffman Electronics Corp., El Monte, CA 91734 |
| 30646 | Beckman Instruments, Inc., Cedar Grove, NJ 07009 |
| 30874 | I.B.M., Armonk, NY 10504 |
| 32001 | Jensen Mfg. Co., Chicago, IL 60638 |
| 33173 | General Electric Comp., Owensboro, KY 42301 |
| 34141 | Koehler Mfg. Co., Inc., Marlboro, MA 01752 |
| 35929 | Constants, Co., Montreal Quebec |
| 37942 | P. R. Mallory & Co., Inc., Indianapolis, IN 46206 |
| 38443 | Marion-Rockwell Corp., Jamestown, NY 14701 |
| 39317 | McGill Manufacturing Co., Inc., Valparaiso, IN 46383 |
| 42931 | Honeywell, Inc., Minneapolis, MN 55408 |
| 42190 | Muter Co., Chicago, IL 60638 |
| 42498 | National Co., Inc., Melrose, MA 02176 |
| 43991 | Monroe Hoffman, Stamford, CT 06904 |
| 49671 | R.C.A., New York, NY 10020 |
| 49956 | Raytheon Mfg. Co., Waltham, MA 02154 |
| 50088 | Mostek, Carrollton, TX 75006 |
| 53021 | Sangamo Electric Co., Springfield, IL 62705 |
| 54294 | Shallcross Mfg. Co., Selma, NC 27576 |
| 54715 | Shure Brothers, Inc., Evanston, IL 60202 |
| 56289 | Sprague Electric Co., North Adams, MA 01247 |
| 59730 | Thomas & Betts Co., Elizabeth, NJ 07207 |
| 59875 | T.R.W. Inc., (Accessories Dwl, Cleveland, OH 44117 |
| 60399 | Torrington Mfg. Co., Torrington, CT 06790 |
| 60707 | Union Carbide Corp., New York, NY 10017 |
| 61854 | United-Carr Fastener Corp., Boston, MA 02142 |
| 63060 | Victoreen Instrument Co., Cleveland, OH 44104 |
| 63743 | Ward Leonard Electric Mt. Vernon, NY 10550 |
| 65083 | Westinghouse (Lamp Div), Bloomfield, NJ 07003 |
| 66092 | Weston Instruments, Newark, NJ 07114 |
| 70100 | Acushnet Capacitor Co., New Bedford, MA 02742 |
| 70109 | Adams and Westlake Co., Elkhart, IN 46514 |
| 70485 | Atlantic India Rubber Works, Inc., Chicago, IL 60607 |
| 70663 | Amperite Co., Union City, NJ 07087 |
| 70903 | Belden Mfg. Co., Chicago, IL 60644 |
| 71126 | Bronson Homer D., Beacon Falls, CT 06403 |
| 71279 | Cambridge Thermionic, Corp., Cambridge, MA 02138 |
| 71294 | Canfield Co., Clifton Forge, VA 24422 |
| 71400 | Bussmann Mfg. Co., St. Louis, MO 63107 |
| 71450 | CTS Corp., Elkhart, IN 46514 |
| 71468 | ITT Cannon Electric Inc., Los Angeles, CA 90031 |
| 71482 | C.P. Clare & Co., Chicago, IL 60645 |
| 71590 | Centralab, Inc., Milwaukee, WI 53212 |
| 71666 | Continental Carbon Co., Inc., New York, NY 10001 |
| 71707 | Cutler-Hammer Inc., Providence, RI 02936 |
| 71729 | Dialight Corp., Brooklyn, NY 11237 |
| 72136 | Electromotive Mfg Co., Willimantic, CT 06226 |
| 72228 | Continental Screw Co., New Bedford, MA 02742 |
| 72259 | Nytronics, Inc., Berkeley Hts, NJ 07922 |
| 72619 | Dialight Co., Brooklyn, NY 11237 |
| 72869 | General Instrument Corp., Newark, NJ 07104 |
| 72765 | Drake Mfg. Co., Chicago, IL 60631 |
| 72794 | Dzus Fastener Co., Inc., West Islip, NY 11795 |
| 72825 | Eby Co., Hugh H, Philadelphia, PA 19144 |
| 72962 | Elastic Stop Nut Corp., Union, NJ 07083 |
| 72982 | Erie Technological Products, Erie, PA 16512 |
| 73445 | Amperex Electronic Corp., Hicksville, LI, NY 11801 |
| 73559 | Carling Electric Co., W. Hartford, CT 06110 |
| 73680 | Elco Resistor Co., New York, NY 10001 |
| 73899 | J.F.D. Electronics Corp., Brooklyn, NY 11219 |
| 74193 | Heinemann Electric Co., Trenton, NJ 08602 |
| 74545 | Hubbell, Stratford, CT 06497 |
| 74861 | Industrial Condenser Corp., Chicago, IL 60618 |
| 74868 | Amphenol RF Division, Danbury, CT 06810 |
| 74970 | Johnson Co., E.F., Waseca, MN 56093 |
| 75042 | IRC Div of TRW, Burlington, IA 52601 |
| 75382 | Kulka Electric Corp., Mt. Vernon, NY 10551 |
| 75491 | Lafayette Industrial Electronics, Syosset, NY 11791 |
| 75608 | Linden & Co., Providence, RI 02905 |
| 75915 | Littelfuse, Inc., Des Plaines, IL 60016 |
| 76005 | Lord Mfg. Co., Erie, PA 16512 |
| 76149 | Mallory Electric Corp., Detroit, MI 48204 |
| 76381 | Minnesota Mining, St. Paul, MN 55101 |
| 76487 | Millen Mfg. Co., Inc., Malden, MA 02148 |
| 76545 | Mueller Electric Co., Cleveland, OH 44114 |
| 76694 | National Tube Co., Pittsburg, PA 15230 |
| 76854 | Oak Mfg. Co., Crystal Lake, IL 60014 |
| 77147 | Patton-MacGuyer Co., Providence, RI 02905 |
| 77166 | Pyrofilm Corp., Whippany, NJ 07950 |
| 77263 | Pierce-Roberts Rubber Co., Trenton, NJ 08638 |
| 77339 | Positronic Industries Inc., Newark, NJ 07101 |
| 77342 | American Machine & Foundry Co., Princeton, IN 47570 |
| 77542 | Ray-O-Vac Co., Madison, WI 53703 |
| 77630 | T.R.W. Electronic Comp., Camden, NJ 08103 |
| 77638 | General Instruments Corp., Brooklyn, NY 11211 |
| 78189 | Shakeproof (Ill. Tool Wks), Elgin, IL 60120 |
| 78277 | Sigma Instruments Inc., South Braintree, MA 02184 |
| 78488 | Stackpole Carbon Co., St. Mary's, PA 15827 |
| 78553 | Tinnerman Products, Inc., Cleveland, OH 44101 |
| 79069 | R.C.A. Rec. Tube & Semicond., Harrison, NJ 07029 |
| 79136 | Waldes Kohinoor Co., New York, NY 11101 |
| 79725 | Wilremold Co., Hartford, CT 06110 |
| 79727 | Continental WIRT Electronics Corp., Philadelphia, PA 19101 |
| 79963 | Zierick Mfg. Co., Mount Kisco, NY 10549 |
| 80009 | Tektronix, Inc., Beaverton, OR 97005 |
| 80030 | Prestole Fastener, Toledo, OH 43606 |
| 80048 | Vickers Inc., St. Louis, MO 63166 |
| 80103 | Lambda Electronics Corp., Melville, NY 11746 |
| 80183 | Sprague Products Co., North Adams, MA 01247 |
| 80211 | Motorola Inc., Franklin Park, IL 60131 |
| 80251 | Formica Corp., Cincinnati, OH 45232 |
| 80258 | Standard Oil Co., Lafayette, IN 47902 |
| 80294 | Bourns Laboratories, Inc., Riverside, CA 92506 |
| 80368 | Sylvania Electric Products, Inc., New York, NY 10017 |
| 80431 | Aw Filter Corp., Milwaukee, WI 53215 |
| 80683 | Hammarlund Co., Inc., New York, NY 10010 |
| 80894 | Pure Carbon Co., St. Mary's, PA 15857 |
| 81030 | International Instrument, Orange, CT 06477 |
| 81073 | Grayhill Inc., LaGrange, IL 60525 |
| 81143 | Isolantite Mfg. Corp., Stirling, NJ 07980 |
| 81312 | Winchester Electronics Co., Inc., Oakville, CT 06779 |
| 81349 | Military Specifications |
| 81350 | Joint Army-Navy Specifications |
| 81483 | International Rectifier Corp., El Segundo, CA 90245 |
| 81751 | Columbia Electronics Corp., Somers, NY 10701 |
| 81831 | Filtron Co., Flushing, NY 11354 |
| 81860 | Barry Wright Corp., Watertown, MA 02172 |
| 82219 | Sylvania Elec. Prod., Emporium, PA 15834 |
| 82270 | Indiana Pattern & Model Works, Lafort, IN 46350 |
| 82389 | Switchcraft, Inc., Chicago, IL 60630 |
| 82647 | Metals & Controls, Inc., Attleboro, MA 02703 |
| 82807 | Milwaukee Resistor Co., Milwaukee, WI 53204 |
| 82877 | Rotron Mfg. Co., Inc., Woodstock, NY 12498 |
| 83003 | Varo Semiconductor Div., Garland, TX 75040 |
| 83033 | Meisner Mfg., Mt. Carmel, IL 62863 |
| 83058 | Carr Fastener Co., Cambridge, MA 02142 |
| 83186 | Victory Engineering, Springfield, NJ 07081 |
| 83617 | Bearing Specialty Co., San Francisco, CA 94101 |
| 83587 | Solar Electric Corp., Warren, PA 16365 |
| 83594 | Burroughs Corp., Plainfield, NJ 07061 |
| 83740 | Union Carbide Corp., New York, NY 10017 |
| 84411 | TRW Capacitor Division, Ogallala, NB 69153 |
| 84635 | Lehigh Metal Products, Cambridge, MA 02140 |
| 84970 | Sarkes Tarzian, Inc., Bloomington, IN 47401 |
| 84971 | T.A. Mfg. Corp., Los Angeles, CA 90039 |
| 86577 | Precision Metal Products, Stoneham, MA 02180 |
| 86684 | R.C.A., (Elec. Comp. & Dev), Harrison, NJ 07029 |
| 86887 | R.E.C. Corp., New Rochelle, NY 10801 |
| 86800 | Cont. Electronics Corp., Brooklyn, NY 11222 |
| 88140 | Cutler-Hammer Inc., Lincoln, IL 62656 |
| 88219 | Gould Nat. Batteries, Inc., Trenton, NJ 08607 |
| 88419 | Cornell Dubilier, Fuquay-Varina, NC 27526 |
| 88627 | K & G Mfg. Co., New York, NY 10001 |
| 89462 | Holtzer Cabot Corp., Boston, MA 02119 |
| 89665 | United Transformer Co., Chicago, IL 60607 |
| 89870 | Berkshire Transformer Co., Kent, CT 06757 |
| 90201 | Mallory Capacitor Co., Indianapolis, IN 46206 |
| 90303 | Mallory Battery Co., Tarrytown, NY 10591 |
| 90634 | Gilfillan Bros. Inc., Los Angeles, CA 90034 |
| 90750 | Westinghouse Electric Corp., Bradford, PA 16701 |
| 90952 | Hardware Products Co., Reading, PA 19602 |
| 91032 | Continental Wire Corp., York, PA 17405 |
| 91146 | I.T.T. (Cannon), Salem, MA 01970 |
| 91210 | Gerber Mfg. Co., Mishawaka, IN 46544 |
| 91293 | Johanson Mfg. Co., Boonton, NJ 07005 |
| 91417 | Harris Semiconductor, Melbourne, FL 32901 |
| 91506 | Augat Brothers, Inc., Attleboro, MA 02703 |
| 91598 | Chandler Co., Wethersfield, CT 06109 |
| 91637 | Dale Electronics, Inc., Columbus, NE 68601 |
| 91662 | Elco Corp., Willow Grove, PA 19090 |
| 91719 | General Instruments Corp., Dallas, TX 75221 |
| 91836 | Kings Electronics, Co., Inc., Tuckahoe, NY 10721 |
| 91916 | Mephisto Tool Co., Inc., Hudson, NY 12534 |
| 91929 | Honeywell, Inc., Freeport, IL 61032 |
| 92519 | Elco Resistor Co., Woodside, LI, NY 11377 |
| 92678 | Edgerton Germeshausen, Georgetown, MA 01830 |
| 92702 | I.M.C. Magnetics Corp., Westbury, NY 11590 |
| 92739 | Amphenol Corp., Redwood City, CA 94063 |
| 92966 | Hudson Lamp Co., Kearny, NJ 07032 |
| 93332 | Sylvania Elect. Prods., Inc., Woburn, MA 01801 |
| 93618 | R & C Mfg. Co. of Penn, Inc., Ramsey, PA 19451 |
| 93916 | Cramer Products Co., New York, NY 10013 |
| 94144 | Raytheon Co., Components Div., Quincy, MA 02169 |
| 94154 | Tung Sol Electric Inc., Newark, NJ 07101 |
| 94271 | Weston Instruments, Inc., Archibald, PA 18403 |
| 94322 | Teledyne, Inc., Manchester, NH 03102 |
| 94589 | Dickson Co., Chicago, IL 60619 |
| 94696 | Magnecraft Electric Co., Chicago, IL 60630 |
| 94800 | Atlas Industrial Corp., Brookline, NH 03033 |
| 95076 | Garde Mfg. Co., Cumberland, RI 02864 |
| 95121 | Quality Components, Inc., St. Marys, PA 15857 |
| 95146 | Alco Electronics Mfg. Co., Lawrence, MA 01843 |
| 95238 | Continental Connector Corp., Woodside, NY 11377 |
| 95275 | Vitramon, Inc., Bridgeport, CT 06601 |
| 95348 | Gordos Corp., Bloomfield, NJ 07003 |
| 95354 | Methode Mfg. Co., Rolling Meadows, IL 60008 |
| 95794 | American Brass Co., Torrington, CT 06790 |
| 95987 | Weckesser Co., Inc., Chicago, IL 60646 |
| 96005 | Hi Q Division of Aerovox Corp., Olean, NY 14760 |
| 96341 | Microwave Associates, Inc., Burlington, MA 01801 |
| 96906 | Military Standards |
| 96991 | Swanson Corp., Mamaroneck, NY 10544 |
| 98474 | Compar, Inc., Burlingame, CA 94010 |
| 98821 | North Hills Electronic, Glen Cove, NY 11542 |
| 99117 | Metavac, Inc., Flushing, NY 11358 |
| 99312 | Varian Associates, Palo Alto, CA 94303 |
| 99378 | Attee Corp., Winchester, MA 01890 |
| 99800 | Delevan Electronics, East Aurore, NY 14052 |

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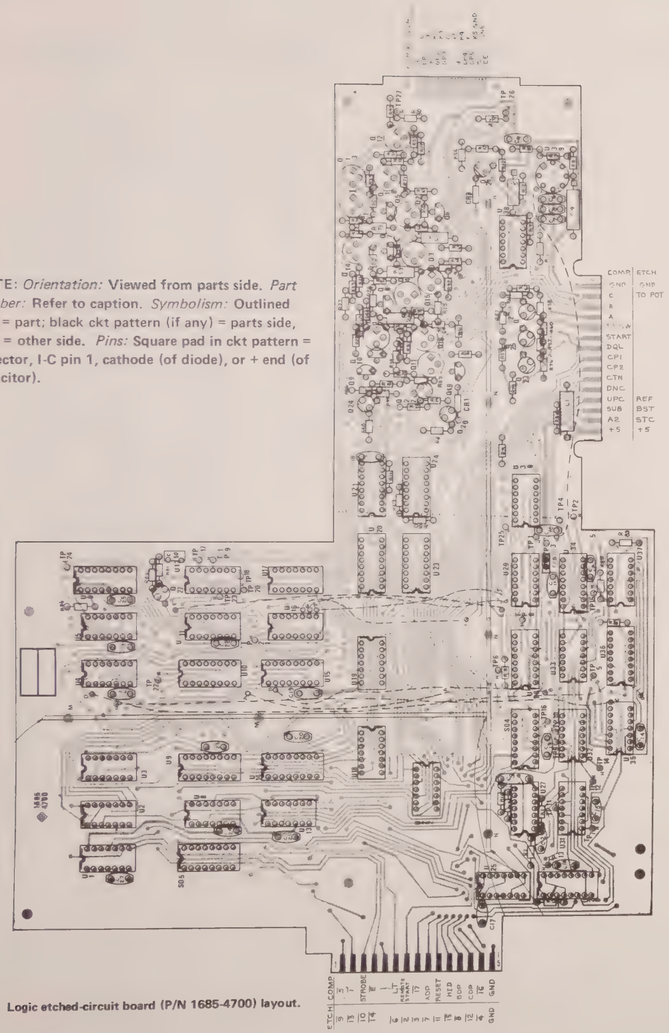
NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).



Logic etched-circuit board (P/N 1685-4700) layout.

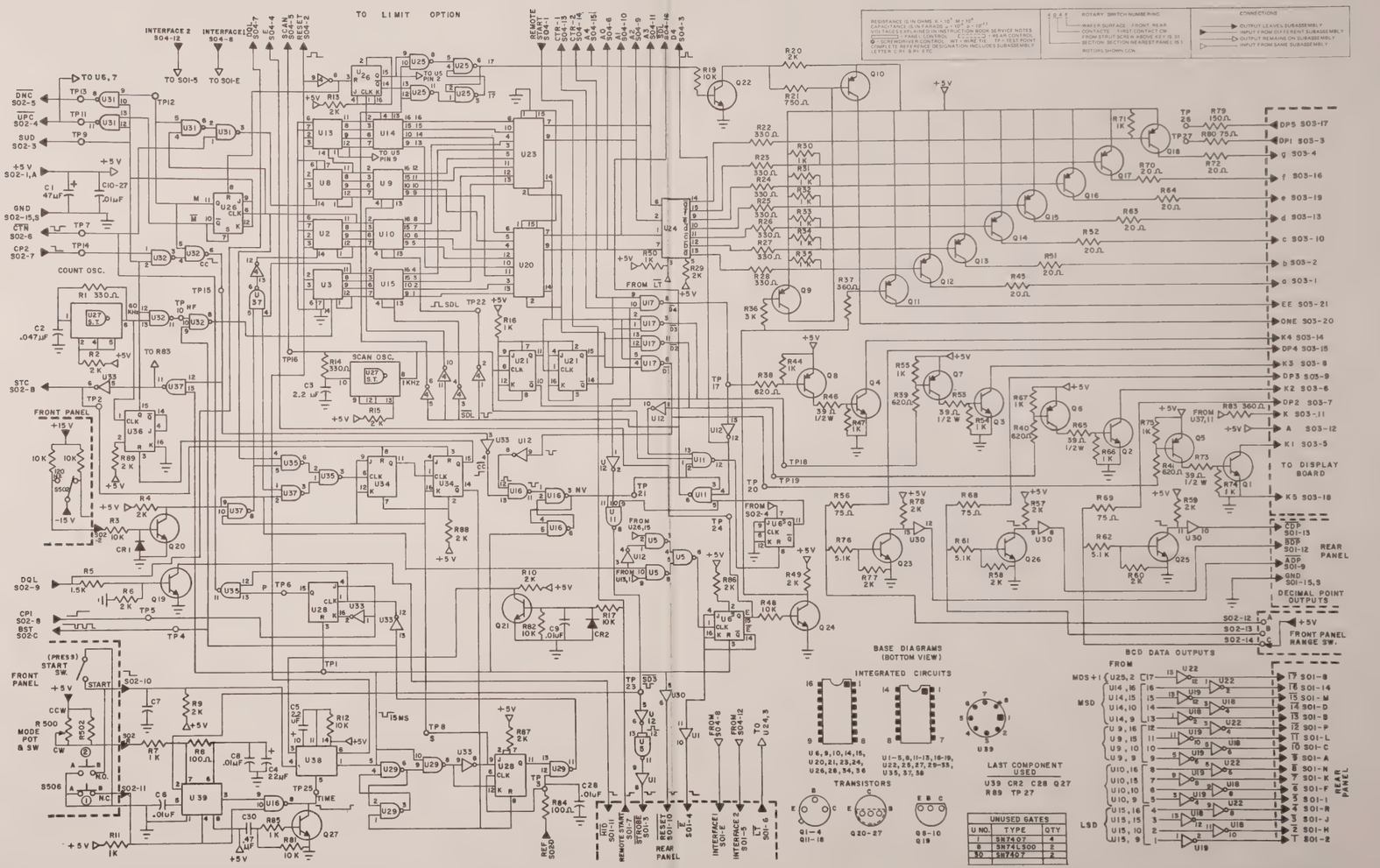


Figure 6-10. Logic board schematic diagram.

## ELECTRICAL PARTS LIST

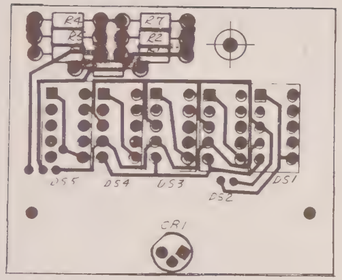
| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | LOGIC BOARD (P/N 1685-4700) PARTS | | | |
| | CAPACITORS | | | |
| C1 | Tantalum, 47 uF ±20% 6 V | 4450-5500 | 56289 | 150D, 47 uF ±20% 6 V |
| C2 | Ceramic, .047 uF +20% 50 V | 4400-2040 | 72982 | 8121, .047 uF ±20% |
| C3 | Ceramic, 2.2 uF ±20% 50 V | 4400-2080 | 72982 | 8141-M050-651-225M |
| C4 | Tantalum, 22 uF ±20% 15 V | 4450-5300 | 56289 | 150D, 22 uF ±20% 15 V |
| C5 | Tantalum, 2.2 uF ±20% 20 V | 4450-4500 | 56289 | 150D, 2.2 uF ±20% 20 V |
| C6 | Ceramic, .01 uF +80-20% 100 V | 4401-3100 | 72982 | 805, .01 uF +80-20% |
| C7 thru C27 | Ceramic, .01 uF +80-20% 100 V | 4401-3100 | 72982 | 805, .01 uF +80-20% |
| C28 | Ceramic, .01 uF ±10% 50 V | 4400-6351 | 72982 | 8121, .01 uF ±10% |
| C29 | Ceramic, .01 uF +80-20% 100 V | 4401-3100 | 72982 | 805, .01 uF +80-20% |
| C30 | Ceramic, 0.47 uF ±20% 50 V | 4400-2054 | 72982 | 8131, 0.47 uF ±20% |
| | DIODES | | | |
| CR1 and CR2 | Type 1N3604 | 6082-1001 | 14433 | 1N3604 |
| | IC SOCKETS | | | |
| S04 and S05 | IC, 16-Contact | 7540-1817 | 71785 | 133-51-02-006 |
| | INTEGRATED CIRCUITS | | | |
| U1 | Digital, Type SN 7407N | 5431-8107 | 01295 | SN7407N |
| U2 and U3 | Digital, Type SN74LS90N | 5431-8690 | 01295 | SN74LS90N |
| U4 | Digital, Type SN74LS04N | 5431-8604 | 01295 | SN74LS04N |
| U5 | Digital, Type SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U6 | Digital, Type SN74LS76N | 5431-8676 | 01295 | SN74LS76N |
| U8 | Digital, Type SN74LS90N | 5431-8690 | 01295 | SN74LS90N |
| U9 and U10 | Digital, Type SN74LS75N | 5431-8675 | 01295 | SN74LS75N |
| U11 | Digital, Type SN74LS10N | 5431-8610 | 01295 | SN74LS10N |
| U12 | Digital, Type SN74LS04N | 5431-8604 | 01295 | SN74LS04N |
| U13 | Digital, Type SN74LS90N | 5431-8690 | 01295 | SN74LS90N |
| U14 and U15 | Digital, Type SN74LS75N | 5431-8675 | 01295 | SN74LS75N |
| U16 | Digital, Type SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U17 | Digital, Type SN74LS03N | 5431-8603 | 01295 | SN74LS03N |
| U18 and U19 | Digital, Type SN7406N | 5431-8106 | 01295 | SN7406N |
| U20 | Digital, Type SN74LS153N | 5431-8753 | 01295 | SN74LS153N |
| U21 | Digital, Type SN74LS76N | 5431-8676 | 01295 | SN74LS76N |
| U22 | Digital, Type SN7406N | 5431-8106 | 01295 | SN7406N |
| U23 | Digital, Type SN74LS153N | 5431-8753 | 01295 | SN74LS153N |
| U24 | Digital, Type 9317D | 5431-9627 | 07263 | 9317594 |
| U25 | Digital, Type SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U26 | Digital, Type SN74LS76N | 5431-8676 | 01295 | SN74LS76N |
| U27 | Digital, Type SN7413N | 5431-8113 | 01295 | SN7413N |
| U28 | Digital, Type SN7476N | 5431-8176 | 01295 | SN7476N |
| U29 | Digital, SN74LS132N | 5431-8732 | 01295 | SN74LS132N |
| U30 | Digital, Type SN7407N | 5431-8107 | 01295 | SN7407N |
| U31 and U32 | Digital, Type SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U33 | Digital, Type SN74LS04N | 5431-8604 | 01295 | SN74LS04N |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | INTEGRATED CIRCUITS (cont) | | | |
| U34 | Digital, Type SN74LS76N | 5431-8676 | 01295 | SN74LS76N |
| U35 | Digital, Type SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U36 | Digital, Type SN74LS76N | 5431-8676 | 01295 | SN74LS76N |
| U37 | Digital, Type SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U38 | Digital, Type SN74121N | 5431-8021 | 01295 | SN74121N |
| U39 | Linear, NE555T | 5432-1040 | 18324 | NE555T |
| | RESISTORS | | | |
| R1 | Comp., 330 ohms ±5% 1/4 W | 6099-1335 | 01121 | RCR07G331J |
| R2 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R3 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R4 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R5 | Comp., 1.5 kilohms ±5% 1/4 W | 6099-2155 | 01121 | RCR07G152J |
| R6 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R7 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R8 | Comp., 100 ohms ±5% 1/4 W | 6099-1105 | 01121 | RCR07G101J |
| R9 and R10 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R11 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R12 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R13 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R14 | Comp., 330 ohms ±5% 1/4 W | 6099-1335 | 01121 | RCR07G331J |
| R15 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R16 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R17 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R19 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R20 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R21 | Comp., 750 ohms ±5% 1/4 W | 6099-1755 | 01121 | RCR07G751J |
| R22 thru R28 | Comp., 330 ohms ±5% 1/4 W | 6099-1335 | 01121 | RCR07G331J |
| R29 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R30 thru R35 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R36 | Comp., 3 kilohms ±5% 1/4 W | 6099-2305 | 01121 | RCR07G302J |
| R37 | Comp., 360 ohms ±5% 1/4 W | 6099-1365 | 01121 | RCR07G361J |
| R38 thru R41 | Comp., 620 ohms ±5% 1/4 W | 6099-1625 | 01121 | RCR07G621J |
| R44 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R45 | Comp., 20 ohms ±5% 1/4 W | 6099-0205 | 01121 | RCR07G200J |
| R46 | Comp., 39 ohms ±5% 1/2 W | 6100-0395 | 01121 | RCR20G390J |
| R47 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R48 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R49 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R50 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R51 and R52 | Comp., 20 ohms ±5% 1/4 W | 6099-0205 | 01121 | RCR07G200J |
| R53 | Comp., 39 ohms ±5% 1/2 W | 6100-0395 | 01121 | RCR20G390J |
| R54 and R55 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R56 | Comp., 75 ohms ±5% 1/4 W | 6099-0755 | 01121 | RCR07G750J |
| R57 thru R60 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R61 and R62 | Comp., 5.1 kilohms ±5% 1/4 W | 6099-2515 | 01121 | RCR07G512J |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | RESISTORS (cont) | | | |
| R63 and R64 | Comp., 20 ohms ±5% 1/4 W | 6099-0205 | 01121 | RCR07G200J |
| R65 | Comp., 39 ohms ±5% 1/2 W | 6100-0395 | 01121 | RCR20G390J |
| R66 and R67 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R68 and R69 | Comp., 75 ohms ±5% 1/4 W | 6099-0755 | 01121 | RCR07G750J |
| R70 | Comp., 20 ohms ±5% 1/4 W | 6099-0205 | 01121 | RCR07G200J |
| R71 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R72 | Comp., 20 ohms ±5% 1/4 W | 6099-0205 | 01121 | RCR07G200J |
| R73 | Comp., 39 ohms ±5% 1/2 W | 6100-0395 | 01121 | RCR20G390J |
| R74 and R75 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R76 | Comp., 5.1 kilohms ±5% 1/4 W | 6099-2515 | 01121 | RCR07G512J |
| R77 and R78 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R79 | Comp., 150 ohms ±5% 1/4 W | 6099-1155 | 01121 | RCR07G151J |
| R80 | Comp., 75 ohms ±5% 1/4 W | 6099-0755 | 01121 | RCR07G750J |
| R81 and R82 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R83 | Comp., 360 ohms ±5% 1/4 W | 6099-1365 | 01121 | RCR07G361J |
| R84 | Comp., 100 ohms ±5% 1/4 W | 6099-1105 | 01121 | RCR07G101J |
| R85 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R86 thru R89 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| | TRANSISTORS | | | |
| Q1 thru Q4 | Type 2N2218 | 8210-1028 | 04713 | 2N2218 |
| Q5 thru Q10 | Type 2N4125 | 8210-1125 | 04713 | 2N4125 |
| Q11 thru Q18 | Type 2N2904 | 8210-1074 | 04713 | 2N2904 |
| Q19 | Type 2N4123 | 8210-1123 | 04713 | 2N4123 |
| Q20 | Type 2N3414 | 8210-1047 | 03508 | 2N3414 |
| Q21 | Type 2N3391A | 8210-1092 | 03508 | 2N3391A |
| Q22 thru Q27 | Type 2N3414 | 8210-1047 | 03508 | 2N3414 |




NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

Display etched-circuit board (P/N 1685-4710) layout.

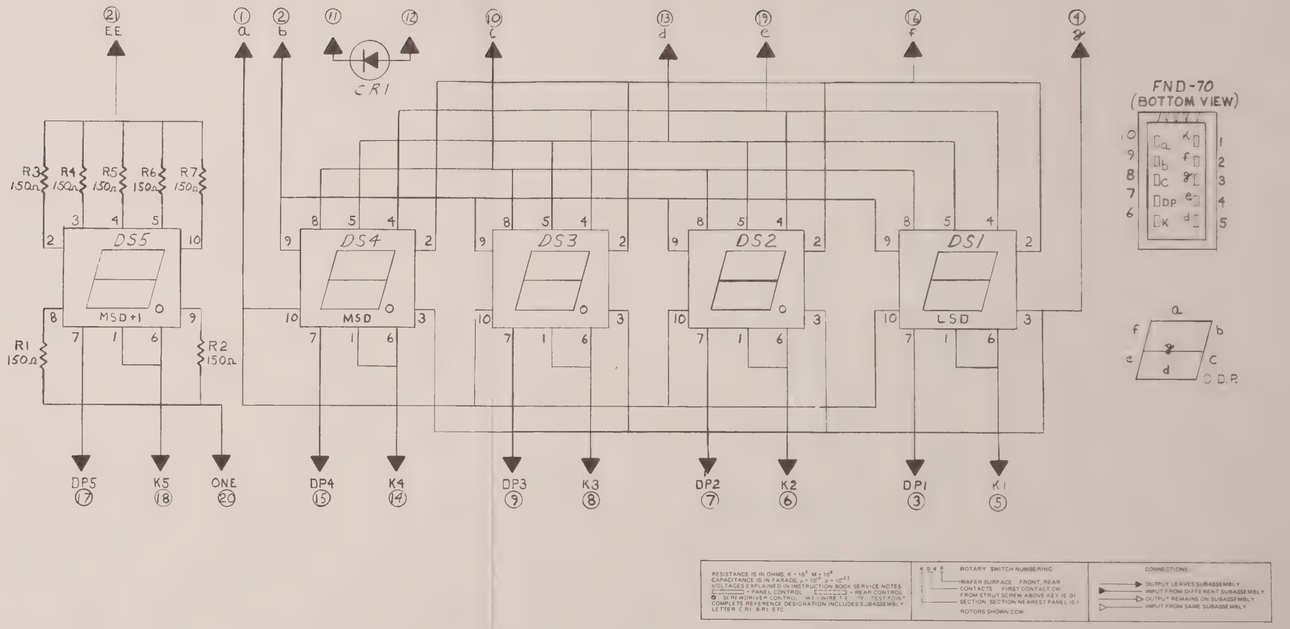


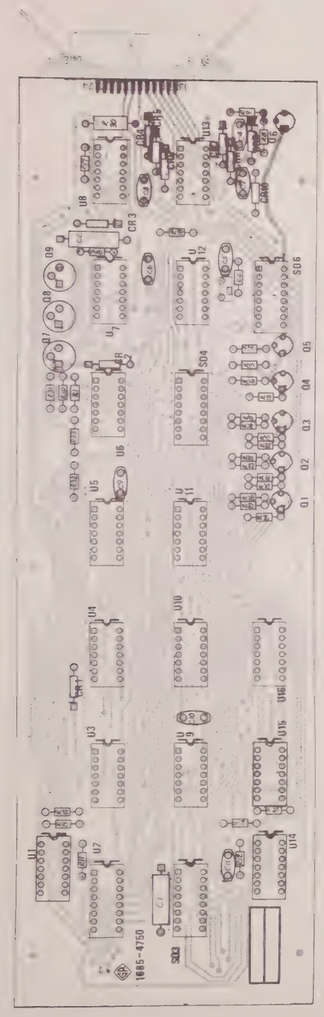

Figure 6-11. Display board schematic diagram.

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | COMPARATOR OPTION BOARD A (P/N 1685-4750) PARTS | | | |
| | CAPACITORS | | | |
| C1 | Tantalum, 47 uF ±20% 6 V | 4450-5500 | 56289 | 150D476X0006B2 |
| C2 | Tantalum, 22 uF ±20%, 15 V | 4450-5300 | 56289 | 150D226X0015B2 |
| C3 | Ceramic, 100 pF ±5% 100 V | 4410-1225 | 72982 | 8131, 100 pF ±5% 100 V |
| C4 thru C11 | Ceramic, .01 uF +80-20% 100 V | 4401-3100 | 72982 | 805, .01 uF +80-20% |
| | DIODES | | | |
| CR1 thru CR10 | 1N645 | 6082-1016 | 14433 | 1N645 |
| | INTEGRATED CIRCUITS | | | |
| U1 | Digital, SN74LS05N | 5431-8605 | 01295 | SN74LS05N |
| U2 | Digital, 9324PC | 5431-9650 | 07263 | 9324PC |
| U3 and U4 | Digital, SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U5 | Digital, SN74LS10N | 5431-8610 | 01295 | SN74LS10N |
| U6 | Digital, SN7473N | 5431-8173 | 01295 | SN7473N |
| U7 | Digital, SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U8 | Digital, SN74121N | 5431-8021 | 01295 | SN74121N |
| U9 | Digital, SN74LS20N | 5431-8620 | 01295 | SN74LS20N |
| U10 | Digital, SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U11 | Digital, SN7414N | 5431-8114 | 01295 | SN7414N |
| U12 | Digital, SN74121N | 5431-8021 | 01295 | SN74121N |
| U13 | Digital, SN7407N | 5431-8107 | 01295 | SN7407N |
| U14 | Digital, SN74LS10N | 5431-8610 | 01295 | SN74LS10N |
| U15 | Digital, SN74LS00N | 5431-8600 | 01295 | SN74LS00N |
| U16 | Digital, SN74LS10N | 5431-8610 | 01295 | SN74LS10N |
| | RESISTORS | | | |
| R1 thru R3 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R4 | Comp., 20 kilohms ±5% 1/4 W | 6099-3205 | 01121 | RCR07G203J |
| R5 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R6 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R8 and R9 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R10 thru R12 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R13 | Comp., 5.1 kilohms ±5% 1/4 W | 6099-2515 | 01121 | RCR07G512J |
| R14 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R15 | Comp., 5.1 kilohms ±5% 1/4 W | 6099-2515 | 01121 | RCR07G512J |
| R17 | Comp., 3.9 kilohms ±5% 1/4 W | 6099-2395 | 01121 | RCR07G392J |
| R18 and R19 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R20 | Comp., 5.1 kilohm ±5% 1/4 W | 6099-2515 | 01121 | RCR07G512J |

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | RESISTORS (cont) | | | |
| R21 | Comp., 620 ohms ±5% 1/4 W | 6099-1625 | 01121 | RCR07G621J |
| R22 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R23 | Comp., 820 ohms ±5% 1/4 W | 6099-1825 | 01121 | RCR07G821J |
| R24 | Comp., 5.1 kilohms ±5% 1/4 W | 6099-2515 | 01121 | RCR07G512J |
| R25 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| R26 | Comp., 620 ohms ±5% 1/4 W | 6099-1625 | 01121 | RCR07G621J |
| R27 | Comp., 820 ohms ±5% 1/4 W | 6099-1825 | 01121 | RCR07G821J |
| R28 | Comp., 16 kilohms ±5% 1/4W | 6099-3165 | 01121 | RCR07G163J |
| R29 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R30 | Comp., 10 ohms ±5% 1/2 W | 6100-0105 | 01121 | RCR20G100J |
| R31 | Comp., 390 ohms ±5% 1/4 W | 6099-1395 | 01121 | RCR07G391J |
| R32 | Comp., 510 ohms ±5% 1/4 W | 6099-1515 | 01121 | RCR07G511J |
| R33 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| R34 | Comp., 510 ohms ±5% 1/4 W | 6099-1515 | 01121 | RCR07G511J |
| R35 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| | SOCKETS | | | |
| S03 and S04 | Cable, 16-contact, PC | 7540-1817 | 71785 | 133-51-02-006 |
| S06 | Cable, 16-contact, PC | 7540-1817 | 71785 | 133-51-02-006 |
| | TRANSISTORS | | | |
| Q1 thru Q4 | Type 2N3414 | 8210-1047 | 03508 | 2N3414 |
| Q5 and Q6 | Type 2N3391A | 8210-1092 | 03508 | 2N3391A |
| Q7 thru Q9 | Type 2N2904 | 8210-1074 | 04713 | 2N2904 |
| | RECEPTACLES | | | |
| S05 | Micro, Ribbon 24-contact | 4230-4024 | 02660 | 57-40240 |
| | DISPLAY BOARD (P/N 1685-4710) PARTS | | | |
| | INDICATORS | | | |
| DS1 thru DS5 | Digital | 5437-1230 | 07263 | FND-70 |
| | DIODES | | | |
| CR1 | Light-emitting, red | 6084-1099 | 13715 | FLV102 |
| | RESISTORS | | | |
| R1 thru R7 | Comp., 150 ohms ±5% 1/4 W | 6099-1155 | 01121 | RCR07G151J |



Comparator etched circuit board 'A' (P/N 1685-4750) layout.

NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

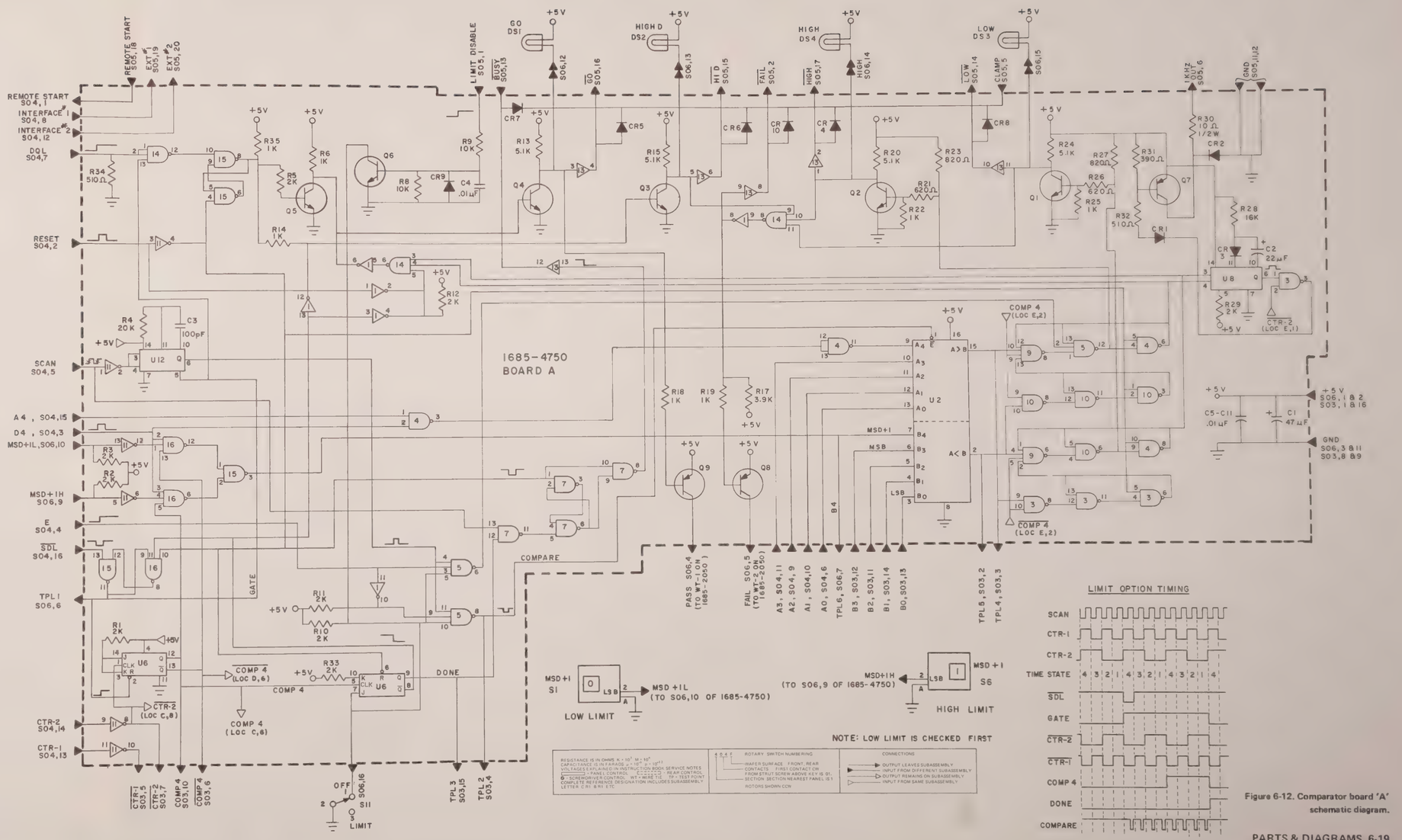
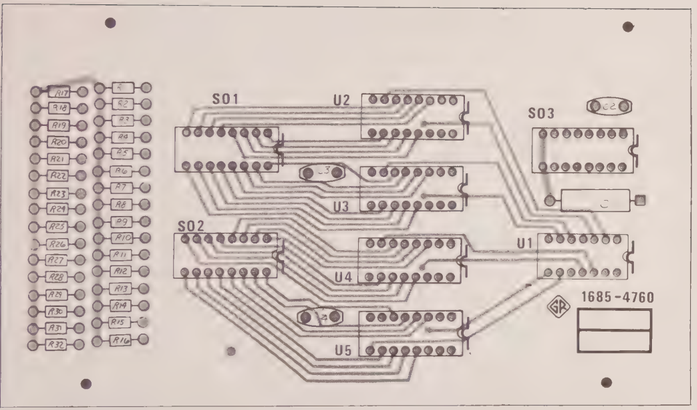



Figure 6-12. Comparator board 'A' schematic diagram.

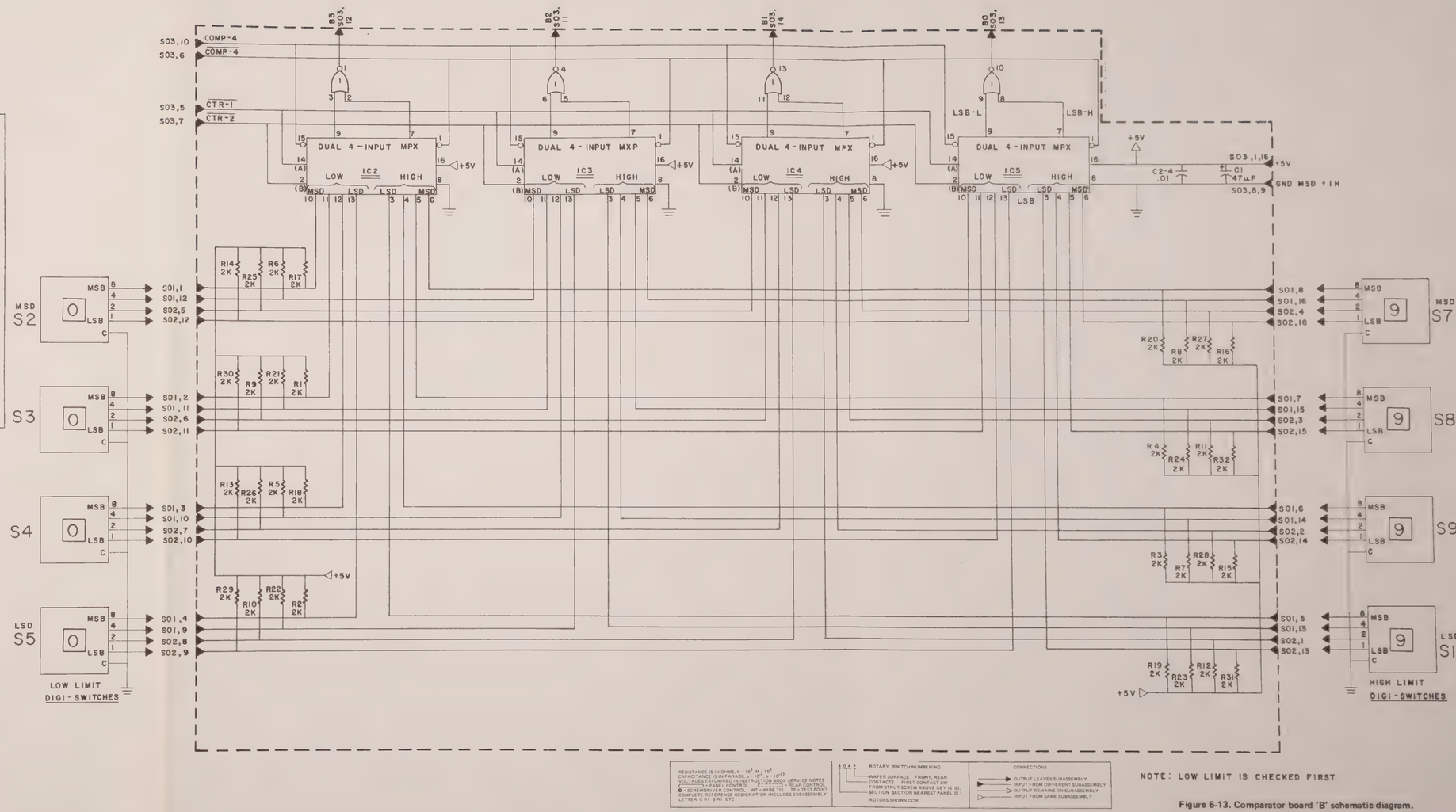
## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | COMPARATOR BOARD B (P/N 1685-4760) PARTS | | | |
| CAPACITORS | | | | |
| C1 | Tantalum, 47 uF ±20% 6 V | 4450-5500 | 56289 | 150D476X0006B2 |
| C2 thru C4 | Ceramic, .01 uF +80-20% 100 V | 4401-3100 | 72982 | 805, .01 uF +80-20% |
| INTEGRATED CIRCUITS | | | | |
| U1 | Type SN74LS02N | 5431-8602 | 01295 | SN74LS02N |
| U2 thru U5 | Type SN74LS153N | 5431-8753 | 01295 | SN74LS153N |
| RESISTORS | | | | |
| R1 thru R32 | Comp., 2 kilohms ±5% 1/4 W | 6099-2205 | 01121 | RCR07G202J |
| SOCKETS | | | | |
| S01 thru S03 | DIP, 16-cont, PC | 7540-1817 | 71785 | 133-51-02-006 |




NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

Comparator etched-circuit board 'B' (P/N 1685-4760) layout.




NOTE: LOW LIMIT IS CHECKED FIRST

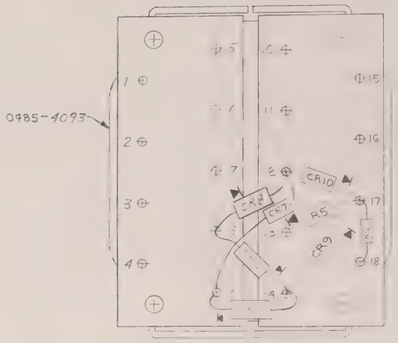
Figure 6-13. Comparator board 'B' schematic diagram.

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | POWER SUPPLY BOARD (P/N 1685-4730) PARTS | | | |
| CAPACITORS | | | | |
| C2 | Ceramic, 1 uF ±20% 50 V | 4400-2070 | 72982 | 8131, 1 uF ±20% |
| C5 and C6 | Ceramic, 1 uF ±20% 50 V | 4400-2070 | 72982 | 8131, 1 uF ±20% |
| C7 and C8 | Ceramic, 0.22 uF ±20% 50 V | 4400-2052 | 72982 | 8131, 0.22 uF ±20% |
| C9 and C10 | Tantalum, 33 uF ±20% 20 V | 4450-5613 | 56289 | 150D, 33 uF ±20% 20 V |
| C11 | Ceramic, 1 uF ±20% 50 V | 4400-2070 | 72982 | 8131, 1 uF ±20% |
| INTEGRATED CIRCUIT | | | | |
| U1 | Linear, Type SG3501 | 5432-1036 | 34333 | SG3501 |
| RESISTORS | | | | |
| R1 and R2 | Comp., 100 ohms ±5% 1/4 W | 6099-1105 | 01121 | RCR07G101J |
| R3 and R4 | Wire-wound, 1 ohm ±5% 2 W | 6760-9105 | 75042 | BWH, 1 ohm ±5% |
| TRANSISTORS | | | | |
| Q1 | Type TIP 32 | 8210-1208 | 01295 | TIP-32A |
| Q2 | TIP 31 | 8210-1207 | 01295 | TIP-31A |

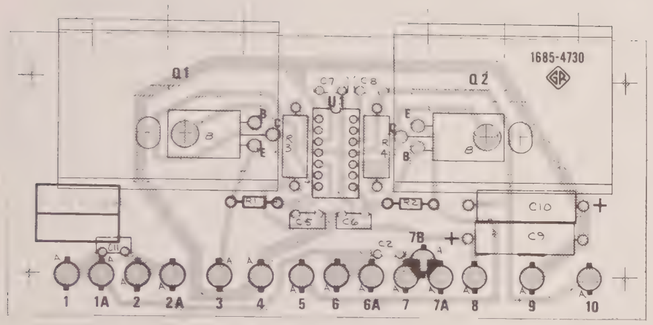
## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | POWER SUPPLY AND TRANSFORMER AND DIODE ASSY (P/N 1685-2020) PARTS | | | |
| TRANSFORMER & BRIDGE ASM | | 1685-2020 | 24655 | 1685-2020 |
| DIODES | | | | |
| CR5 thru CR8 | Type 1N4003 | 6081-1001 | 14433 | 1N4003 |
| CR9 and CR10 | Type 1N459A | 6082-1011 | 14433 | 1N459A |
| RESISTORS | | | | |
| R5 | Comp., 10 kilohms ±5% 1/4 W | 6099-3105 | 01121 | RCR07G103J |
| R6 | Comp., 1 kilohm ±5% 1/4 W | 6099-2105 | 01121 | RCR07G102J |
| TRANSFORMER | | | | |
| T1 | Power | 0485-4093 | 24655 | 0485-4093 |




WT9 TO WT14 BY CR6 (CATHODE TO WT9)
WT9 TO WT12 BY CR7 (CATHODE TO WT9)
WT14 TO WT8 BY CR5 (CATHODE TO WT14)
WT8 TO WT12 BY CR8 (CATHODE TO WT12)
WT12 TO WT17 BY CR10 (CATHODE TO WT17)
WT14 TO WT17 BY CR9 (CATHODE TO WT17)
WT13 TO WT17 BY R5
WT17 TO WT18 BY R6

Transformer and Diode Assembly (P/N 1685-2020) layout.




NOTE: *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Outlined area = part; black ckt pattern (if any) = parts side, gray = other side. *Pins:* Square pad in ckt pattern = collector, I-C pin 1, cathode (of diode), or + end (of capacitor).

**Power Supply etched-circuit board (P/N 1685-4730) layout.**

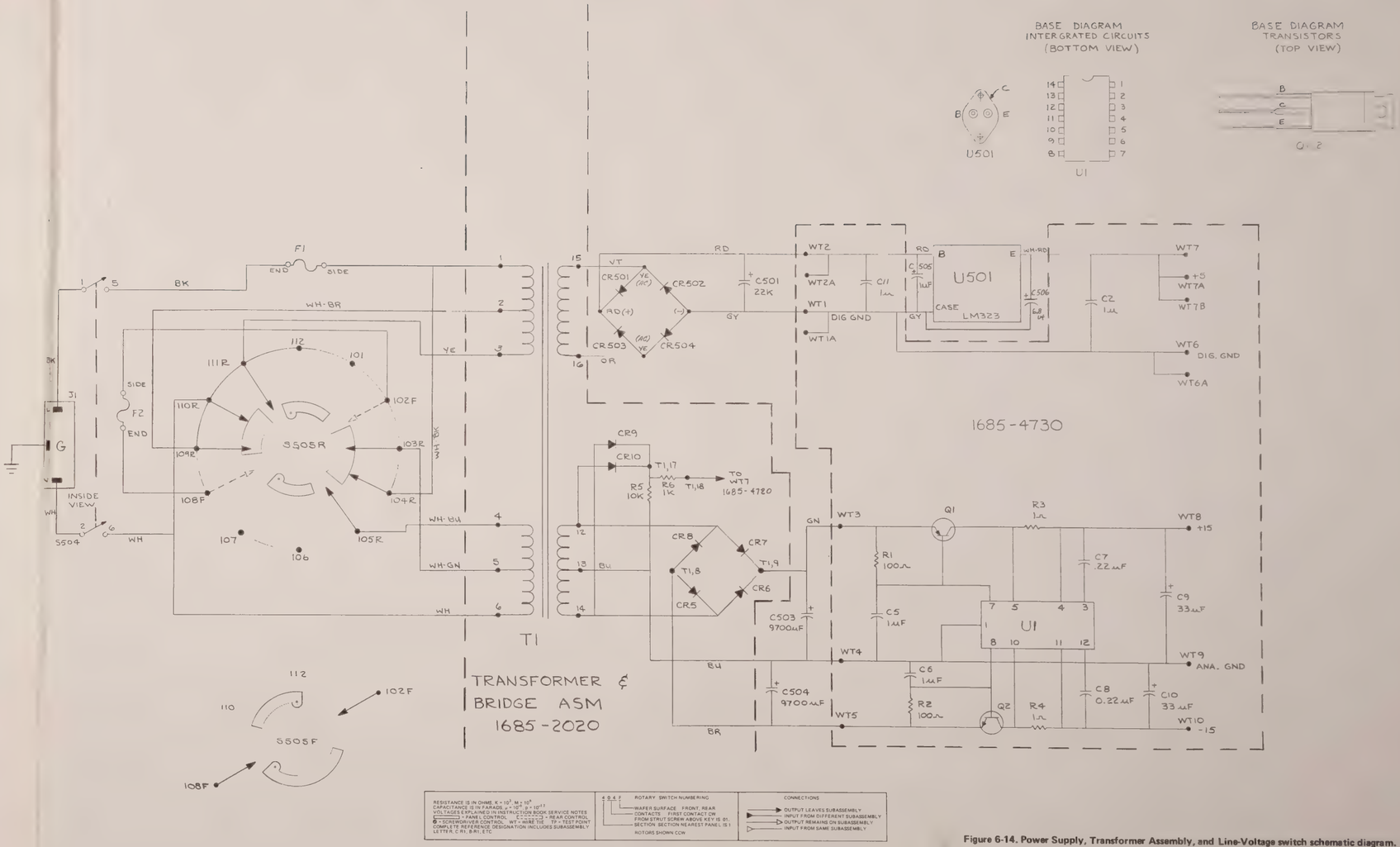



**Figure 6-14. Power Supply, Transformer Assembly, and Line-Voltage switch schematic diagram.**

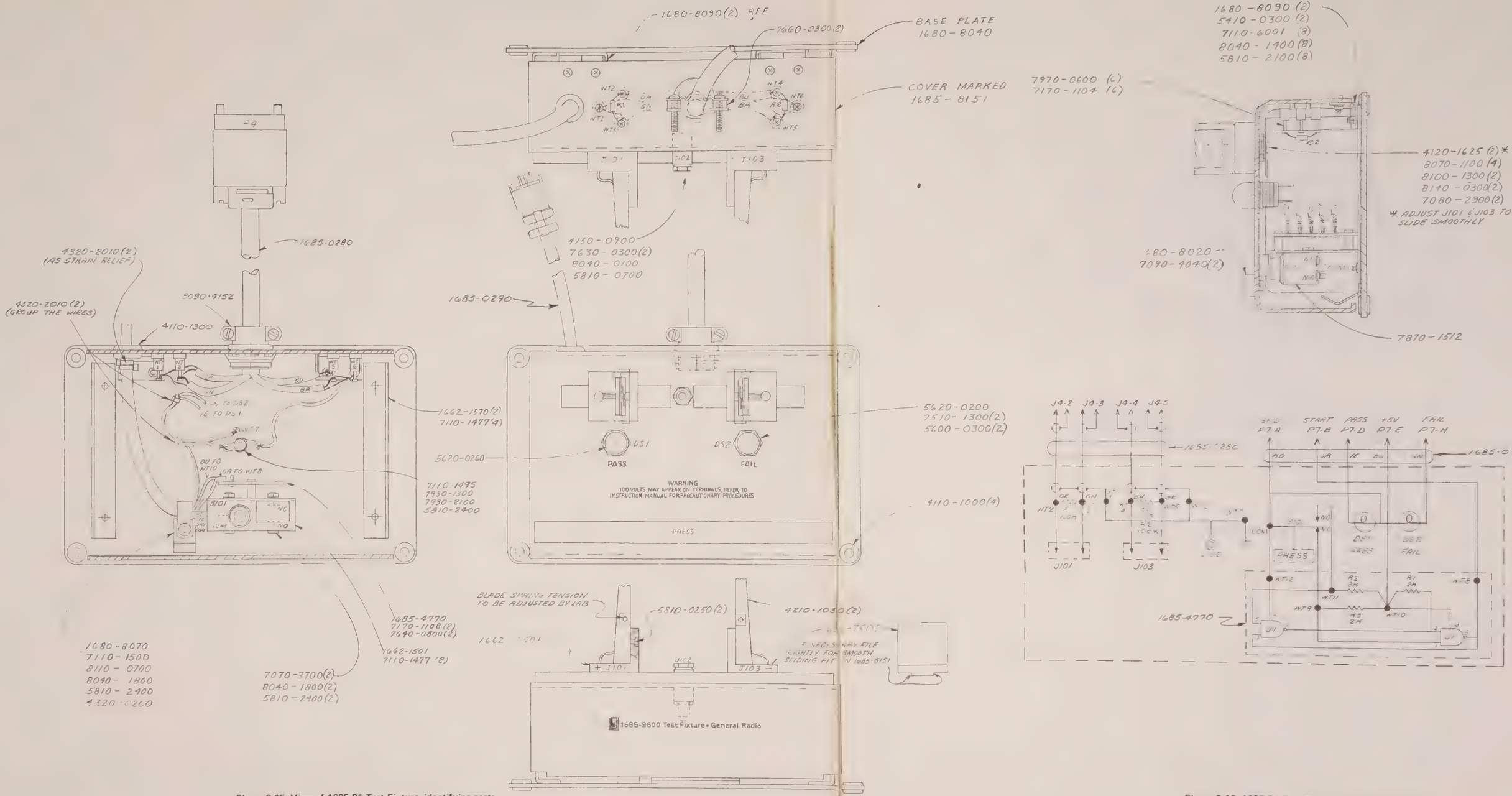
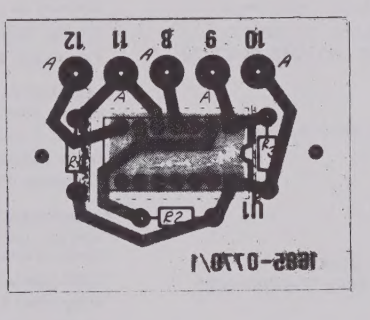



Figure 6-15. View of 1685-P1 Test Fixture, identifying parts.

Figure 6-16. 1685-P1 Test Fixture schematic diagram.

## ELECTRICAL PARTS LIST

| Ref Des | Description | GR Part No. | Fed Mfg Code | Mfg Part No. |
|---|---|---|---|---|
| | TYPE 1685-P1 TEST FIXTURE (P/N 1685-9600) PARTS | | | |
| INTEGRATED CIRCUITS | | | | |
| U1 | Digital, Type SN7403 | 5431-8103 | 01295 | SN7403N |
| RESISTORS | | | | |
| R1 thru R3 | Comp., 2 kilohms ±5% | 6099-2205 | 01121 | RCR07G202J |




**NOTE:** *Orientation:* Viewed from parts side. *Part number:* Refer to caption. *Symbolism:* Tone area = part; black ckt pattern = parts side.

**Switch Anti-Bounce etched-circuit board (P/N 1685-4770) layout.**

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